The Dynamic Futures for NRC Mission Areas

Key Takeaways

U.S.NRC

United States Nuclear Regulatory Commission

Protecting People and the Environment

Contents

Key Terms and Acronyms

Advanced Reactor	Non-light Water Reactor
AI	Artificial Intelligence
CDF	Core Damage Frequency
CISF	Consolidated Interim Storage Facility
Digital I&C	Digital Instrumentation and Controls
EDO	NRC Office of the Executive Director for Operations
eSWP	Enhanced Strategic Workforce Planning
FAA	Federal Aviation Administration
FDA	U.S. Food and Drug Administration
FEVS	Federal Employee Viewpoint Survey
GAO	U.S. Government Accountability Office
IAEA	International Atomic Energy Agency
IT/IM	Information Technology/Information Management
IoT	Internet of Things
LERF	Large Early Release Frequency
LWR	Light Water Reactors
Marker	Trail markers that hint at which signpost, and ultimately which future, you might be moving toward
NGO	Non-Governmental Organization
NHTSA	National Highway Traffic Safety Administration
OCHCO	NRC Office of the Chief Human Capital Officer
OMB	U.S. Office of Management and Budget
QHO	Quantitative Health Objective
RPA	Robotic Process Automation
Scenario	A rich, data-driven narrative description of the external environment in which an organization may need to operate in future
SMED	Single Minute Exchange of Dies
Signpost	Precursor towards the direction of the future. Reflects the broader conditions in the environment being monitored
SMRs	Small Modular Reactors
TSA	Transportation Security Administration
UAV	Unmanned Aerial Vehicles

Key Takeaways

While the future external environment in which the NRC will operate in 2030 is uncertain, it is far from entirely random. (See Appendix A for a summary of the how the external environment in which the NRC operates might evolve through 2030 and beyond). Monitoring and anticipating how the future will unfold can allow the NRC to be more agile and resilient to the range of possible futures, placing the NRC in a far better position to thrive regardless of whatever future emerges.

This document describes five key takeaways from the scenarios;

1. Increasing the Agility of the Organization;
2. Enhancing the NRC's Strategy, Governance, and Culture;
3. Preparing for Human Capital Changes;
4. Increasing Efficiency Through Technology;
5. Engaging with Future Stakeholders.

The key takeaways are grouped by theme and represent areas where the NRC may want to consider acting to meet the challenges of a changing industry, improve delivery on current and future missions, and prepare its workforce for 2030 and beyond.

Many of the actions aligned to the takeaways are detailed, and are applied across the four scenarios regardless of which future unfolds. Other actions should be viewed as "hedges" that the NRC could take to prepare itself to respond for particular futures, or to keep action opportunities open in case a particular future unfolds. (This section will specify where such actions relate specifically to one of the four scenarios (Nuclear Takes Off; What's Old is New Again; Gone with the Wind; and Great Idea, But Not For U.S). Yet other actions will be agile actions, to keep the NRC ready to adapt and respond quickly to multiple futures.

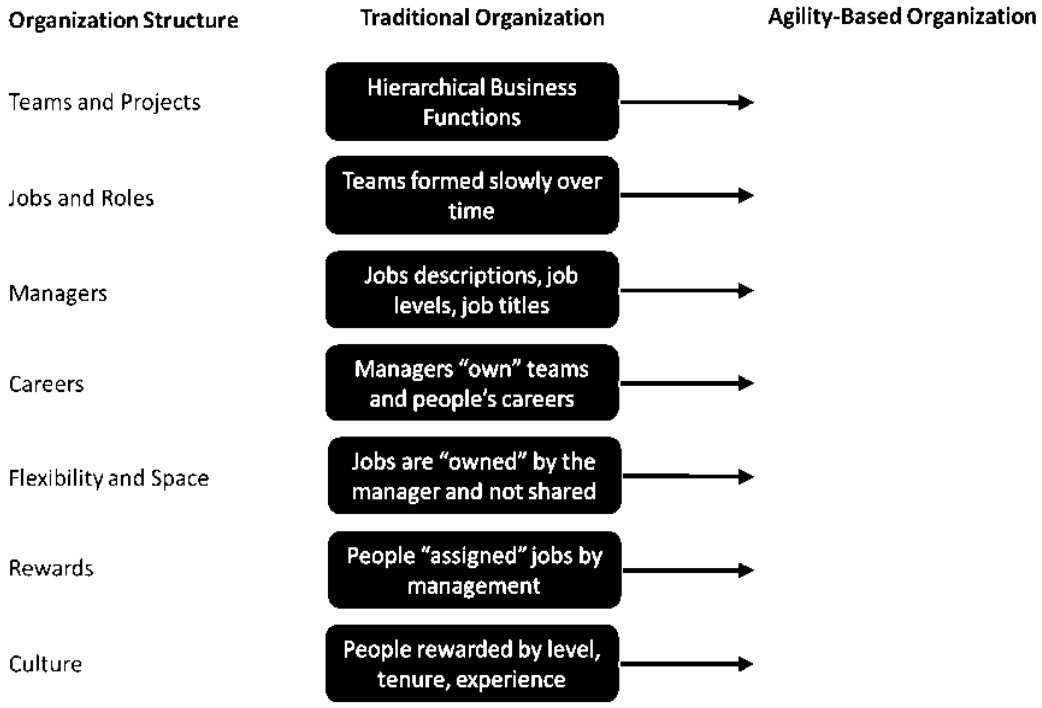
Some of the actions suggested here, particularly detailed options, are actions that the NRC should consider in the near-term in preparation for 2030. Others are actions that are more suitable for addressing particular scenarios. To understand when to enact scenario-specific actions, the NRC could consider how to recognize how the future might be unfolding and which aspects of the future might resemble particular scenarios. This could be done through identifying a set of "signposts" (i.e., precursors towards the direction of the future that reflect the broader conditions in the environment being monitored). Having identified the appropriate signposts, the NRC could then consider developing and regularly tracking a set of "markers" (i.e., clues and indications about which signposts the NRC external environment is moving toward).

The key takeaways and their corresponding suggested actions outlined in this document do not necessarily represent new initiatives. In many cases, they are suggestions to refine processes and initiatives that are already in the planning or execution stage based on the insights gained from the scenario planning efforts. These will allow the NRC to best prepare for a range of possibilities for whatever the future holds. To succeed, the NRC will need to hold itself accountable for the actions needed to prepare for the future and ensure that there is shared responsibility to take those actions forward.

The NRC's need for increased agility (i.e., the ability to act quickly and easily) in the world of 2030 and beyond emerged across all scenarios. Within each scenario, there is a premium on agility that stems from the need to ramp up or down certain activities in response to changing volumes as well as from requirements for new approaches in response to anticipated innovation in nuclear technologies and reactor design. The NRC will also want to adapt to new types of licensees and business models, more performance-based regulatory approaches, and a shifting portfolio with regard to reactors and nuclear materials. The need to be agile becomes even more urgent when looking across scenarios and recognizing that the path forward is likely to twist and turn, potentially shifting from one scenario to another in response to changing circumstances and sudden events.

Agility is more than just individuals having a flexible mindset or responding quicker. It is reflected in the organization's approaches to areas such as projects, staffing, resources, and structure. The characteristics of an agile organization are described in Figure 1, below. These characteristics are not limited to the private sector and are equally applicable to federal government organizations. The Federal Aviation Administration (FAA), for example, has acted to make its Aircraft Certifications Service more agile to support industry innovation more efficiently and effectively in the future for aircraft weighing 19,000 pounds or less and with 19 or fewer passenger seats. According to the FAA, this has been accomplished by "focusing FAA resources on up-front planning, the use of performance-based standards and a robust risk-based systems oversight program, while leveraging industry's responsibility to comply with regulations." The FAA said it replaces prescriptive requirements with performance-based standards and considers consensus-based compliance methods for specific designs and technologies.[i] The rewritten certification regulations also better aligns with those of foreign partners.

Figure 1: Characteristics of an Enterprise Organized for Agility[ii]



While it is not necessary nor, perhaps, desirable for the NRC to reorganize completely as an agility-based organization, the adoption of some aspects of the agile organization in the most dynamic aspects of its operations where dramatic change and innovation may occur in the future would enable the NRC to respond more readily to an evolving future.

Several specific actions in these areas that may help lay the foundations of agility across the NRC are listed here followed by some considerations to build organizational units specifically focused on agility. These suggestions build on the transformation and innovation efforts that the NRC has already started based on the recommendations from Project Aim, which sought to find ways for the NRC to better adapt to the dynamic environment of 2020. The NRC is already implementing some of the recommendations in this section such as flowing resources to certain projects.

Understand Required Competences and Timing

To operate effectively in a project-oriented structure there must be a clear understanding of the competences and other resources required to accomplish the task successfully. Each agile work project has a well-specified outcome and a completion date commitment (typically on a shorter-than-traditional cycle as discussed below). Once the project team is assured of having the necessary skills and resources, it self-organizes to achieve the desired outcome on time. A clear picture of the competences a project requires and a full inventory of the skills of the organization are necessary to make this work for a project. Timely completion is needed to make this work successfully across projects. This raises the importance of transparency and good data capture and learning on the project times. It also raises the importance of

knowledge management, as information known only by a single individual potentially becomes a bottleneck across projects and time.

Break Work Into Smaller Outcome-Focused Projects

Breaking all major projects into smaller project is one of the most visible ways that agile project management differs from the Tiger Teams familiar to the NRC. Agile organizations execute large complex projects by breaking them down into smaller pieces each with a clearly defined outcome and an understanding of the dependencies between the pieces. These smaller elements are then completed iteratively in rapid-cycles, often in parallel, resulting in a shorter overall project duration. This requires an articulation of the key elements and their interaction and a definition of what success looks like for each. This greater specificity and smaller task focus enables a better matching of skills to the elements of the project and enables greater parallel execution shortening the project's critical path. It also enables completion of many tasks while ambiguity is being iteratively resolved concerning others.

Flow Resources to Projects

What makes organizations more agile in practice is not just the ability to know what competences are required and to break large complex projects down into more rapid-cycle pieces, but also the ability to flow resources into and out of projects on an as-needed basis effectively. This ensures valuable, scarce skills are deployed at their most useful point. To do this successfully in the context of the NRC, a large organization that continues to execute many activities in a more traditional steady-state hierarchy, imposes additional requirements on the organization. The NRC would need to have an up-to-date knowledge of employees' current skills and deployment. It should consider its ability to track and account for both traditional roles and project-oriented roles in its performance tracking and rewards system. It should consider a technology acquisitions and contracting process that can execute much faster than is traditional for government while maintaining adequate protections. These all present challenges, but they are challenges addressed by government agencies today.

Perhaps more challenging is the different mindset that is required to execute outcome-focused tasks more quickly without the protection afforded by traditional hierarchy and long-established methods. A look back at Figure 1 suggests this is as much a cultural shift as a shift in management systems. When discussing how the NRC would need to adapt to a changing future, many internal NRC interviewees cited the need to be more agile and the need to be more fully risk-informed. However, currently there does not seem to be a universally shared understanding of what that means precisely or what that implies for the NRC or specific behaviors. If people are to come together in agile project teams, they will need to share a common language and understanding of what the organization means and believes about these and other important priorities.

Reach Out to The NRC's Network for Resources

In agile organizations, project team members are not limited to the organization's current personnel. Reaching beyond the NRC to access critical resources in other networks such as the nuclear industry, nuclear experts in other federal agencies, and other foreign regulators extends the organization's ability to quickly match skills and project requirements. This can take many forms and is most effective when organizations maintain a complete inventory of their skills. It may involve contracting with outside experts, or "borrowing" and "lending" personnel between organizations through details. It may involve connecting to outside knowledge rather than individuals if the NRC were to orchestrate greater alignment with other regulators or identified aspects of the work of other regulators that could be more directly leveraged.

It might involve using crowdsourcing, an area currently being actively explored by the NRC, to develop insights for rule-making, research, and other NRC functions. Crowdsourcing can utilize in-person groups,

synchronous or asynchronous virtual meetings, or social media. The set of people involved can be broad and allowed to opt-in (which is fitting for applications where a cost-effective means of collecting public input is sought) or, for the NRC's mission-related and innovative work a carefully chosen set of experts can be approached.

Encouraging crowd participation through prize challenges could also foster agility and expand the number and diversity of individuals, organizations and teams tackling issues that advance the NRC's mission or foster innovation. The use of prize competitions by the federal government has increased significantly since the passage of the America COMPETES Reauthorization Act of 2010. The GSA estimates that since 2010 federal agencies have conducted more than 840 prize competitions and offered more than $280 million in prize money.[iii] To be effective prize challenges, and all forms of crowdsourcing, require careful design ahead of time.

At the heart of all of this collaborative outreach is the recognition that no matter how good an organization's people are, there are other good people outside the enterprise and accessing their efforts and insights can help to address new challenges more quickly and easily.

When Possible, Minimize Constraining Actions

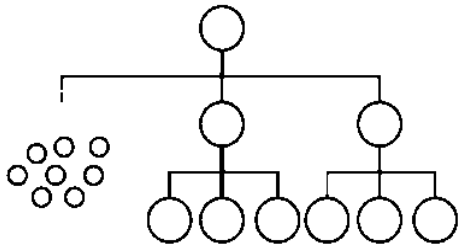
It will not always be possible to take action without some degree of irreversibility and those actions have the potential to restrict the options available to future decision makers. The agile organization tries to remain mindful of the options it may be limiting by the actions it takes today. There are times when major commitments must be made today despite future uncertainty; we call these focused investments. These occur when lead times for action are so long or the advantage of moving earlier is so great that investment is justified to capture a potential future opportunity or reduce a potential future risk. Our discussions identified some areas where the NRC might consider such focused investments. This included preparing for the regulation of advanced reactors on the horizon, as well as preparing for regulating developments in existing technology such as SMRs and digital instrumentation and controls (I&C).

Trying to minimize constraining actions is similar to a hedging strategy (i.e., small investments today that keep action opportunities open until it becomes clearer that a particular future is unfolding). For example, when selecting a new IT application, paying more for IT that will ensure upward and downward scalability through the cloud is an example of paying a little more today to avoid potential constraints of what will become legacy hardware and software in the future. Similarly, a statement that a particular approach will be used going forward for all applications potentially restricts examiners in the future when faced with a novel application. This restricted future flexibility can sometimes be avoided at little or no cost. As noted, one cannot completely avoid affecting the future options by today's actions, but the agile goal is to minimize the constraints created for future actions.

Be Prepared to Rethink Structure

As noted earlier, some areas of the organization may require more innovation than others in the future. Two of the four scenarios (Nuclear Takes Off and Great Idea, But Not for U.S.) consider the development and adoption of advanced reactors. Nuclear Takes Off and What's Old is New Again anticipate significant expansion of new industrial applications. These areas and others (e.g. continued development of SMRs) may provide an opportunity to create a group that pushes itself to be more agile in order to be responsive to these developing needs. This is consistent with an often-recommended approach to enhancing agility by protecting the core and disrupting the edge, i.e., find the areas of the organization that most require agility and institute new ways of working there that are more project focused, rapid and flexible (see Figure 2).

Figure 2: Creating an Agile Group "At the Edge"



Two candidates for the focus of such a group came up during the course of this work, though others may also exist or emerge in the future. The first focuses on emerging nuclear uses, specifically in the area of new medical isotopes and technologies. This offers an attractive focus area in which to build agile skills. It is already an area of focus for the NRC as evidenced by the recent exploration of emerging technologies and is relatively discrete from other aspects of the NRC's work. Building an agile unit in this area could provide an opportunity to explore what could be done within existing regulations to be more flexible and in a shorter time frame that still supports the NRC's mission of safety and security. Internal participants through interviews and in workshops identified this as a potential area where greater agility was needed. Piloting agile project management here would build NRC skills in dealing with innovative applications and provide a rich testbed for external collaboration / engagement as Agreement States, the advisory committee on isotopes, other government health regulators, and potentially new types of license applicants and new material users who are relevant to the broader ecosystem.

The second agile option identified was to focus on existing NRC processes. Participants in workshops and interviews cited a desire for faster, more agile, and more certain processes involved in areas such as licensing, license amendments, new regulations, review of safety findings, and decommissioning. In the near-term future, these areas may have a larger relevant experience base to draw upon than the medical field, which is anticipating more near-term disruption. The taking of complex existing process and transforming them into something more agile involves not only the tools of the agile method, which originated in programming, but also the tools of just-in-time. The NRC could consider the tools that originated with Single Minute Exchange of Dies (SMED) techniques. SMED seeks to identify which steps can be made "external" to the process (i.e., taken off the timeline's critical path) to be performed in parallel with other activities or just once to serve multiple steps and the targeted use of technology to make a process step shorter and less variable. Digital technologies, described in a later section, offer significant opportunities to make existing processes more efficient and potentially for NRC staff to be more effective.

Whatever its focus, this agile group would not only serve the most rapidly evolving parts of the NRC's mission areas but could also serve as a test-bed for new approaches and policies that could be rolled out to the rest of the organization.

With or without an agility-focused group within the organization, there will be a need for the NRC to continue to be prepared to adapt the organizational structure as the future unfolds. Both the high-growth scenarios (What's Old is New Again and Nuclear Takes Off) and the low-growth scenarios (Gone with the Wind and Great Idea, But Not for U.S.) shift the scale of operations and thus affect the number of people to be managed and the number of sites to be regulated. The scope of activities also varies across the scenarios, e.g., with more technologies in the higher-innovation scenarios. In discussions of the future

scenarios, the role and the number of regional offices appeared to be an area where scale and scope changes are likely to call for action in the future. Depending on the level and type of activity across the country, the NRC may need to adjust the activities of the regional offices vis-à-vis local and headquarters activities. SMRs and advanced reactors will require oversight but may not warrant full-time on-site presence. Different regions may also exhibit very different growth rates with regard to the nuclear industry. These future uncertainties mean that the NRC should be prepared to adapt structure on an ongoing basis as scale and scope shift over time.

The need to address the NRC's strategy, governance, and culture to prepare for the potential external environment of 2030 and beyond was a common theme both within the identified scenarios and across the set of possible futures. Broadly, the uncertain future will call for an increasingly adaptive strategy, governance that accommodates the anticipated rate of change, and a culture that is more flexible going forward. These are not so much criticisms of any past practices as they are recognition that the areas addressed by the NRC's mission could evolve rapidly in coming years.

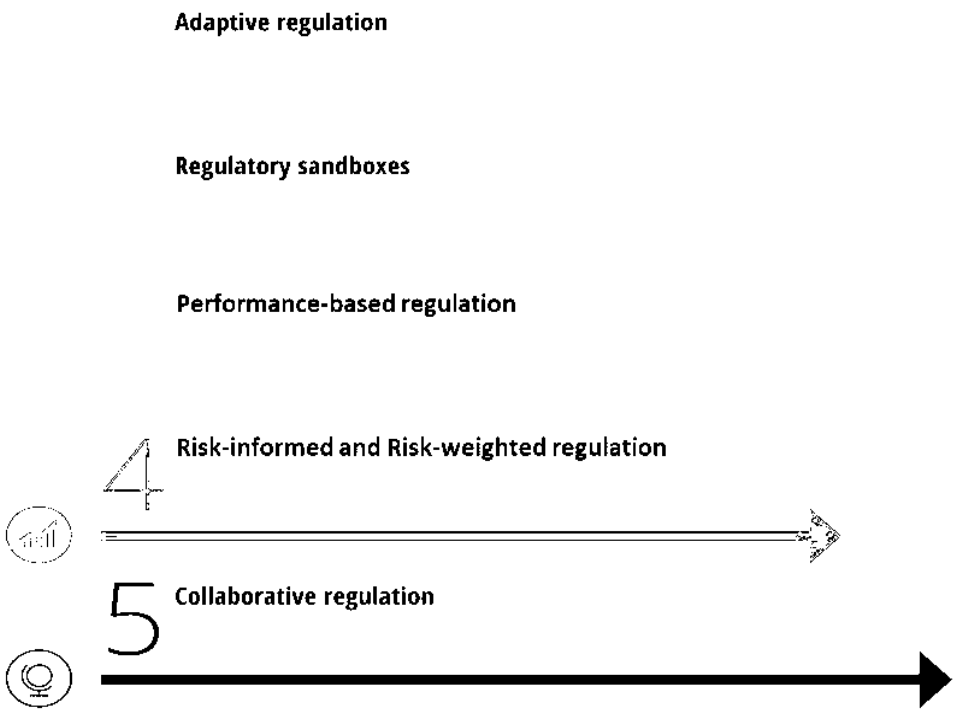
Strategy

Strategy, when well-articulated, does more than just set goals and targets aligned to the mission. A well-articulated strategy guides the organization by answering the questions: "Where should we focus?," "How will we be successful?," and "What capabilities will we need?." These questions should be answered in a fashion that allows the NRC to continue its mission to protect public health and safety, but without unnecessarily stifling innovation (e.g., in Nuclear Takes Off), while continuing to stay abreast of international activities (a challenge in Great Idea, But Not for U.S. where the innovation is primarily coming from China and Russia). Several interviewees, both internal and external to the NRC, noted that the NRC strategy of the future might need to be more focused on areas that bring the greatest value for resources spent to avoid unnecessary burdens or impacts to the return on investment for licensees. Clearly, the areas of focus will vary depending on how the future unfolds.

To do this effectively, the NRC should continue revisiting the NRC strategy periodically. The Government Performance and Results Act Modernization Act (GPRAMA) of 2010 requires certain agencies to produce a new strategy on a four-year cycle. This may be appropriate for some agencies; the Social Security Administration, for example, has a strong ability to project future demand based on demographics. The level and nature of future demand is much less predictable for the NRC. The NRC is evaluating internal and external markers that would indicate the potential of particular futures unfolding and thus a need to revisit its strategy, and considering approaches for tracking those markers. This should also help to reinforce an external awareness within the NRC. The four scenarios are just four possible futures from among many and the tracking of the external environment should promote a "heads up" mindset that should help the NRC to identify earlier whatever changes may occur. At times, a new strategy may be needed. More often, a need to reprioritize activities or timing will be the likely result.

In addition to the NRC's strategy for the enterprise, the NRC's strategy for regulation is also expected to evolve. The NRC has earlier identified the importance of bringing a risk-informed approach to its mission. This is consistent with trends seen in other regulators who are regulating emerging technologies and/or changing business models and industries. Five key trends that have been observed globally for those regulating in disruptive environments, and how they apply to the NRC, are summarized in Figure 3.

Figure 3: Five Regulatory Principles to Tackle Emerging Technologies [iv]



The following lists how these approaches might apply to the NRC in the future. Indeed, for many of the approaches (adaptive regulation, performance-based regulation, risk-informed regulation, and collaborative regulation), the NRC already has specific initiatives underway.

Adaptive Regulation

Rapid change, shifting business models, and experimentation are hallmarks of technology-driven industries such as the nuclear industry but present fundamental challenges to regulation. The need for the NRC to revisit and evolve regulation as times and technology change was cited in internal and external interviews. This is not just about developing regulations to address whichever new technologies arise, but also about considering how the NRC's overall regulatory approach is suited to a world where the technology it regulates continues to evolve at an ever-faster pace. All the scenarios developed envision that there will be at least incremental innovation in nuclear reactor technology by 2030, and many envision innovations in the technologies and business models in decommissioning, nuclear waste management, and the use of nuclear materials. The NRC could thus consider adopting an adaptive regulatory approach that allows the NRC to adjust quickly to developments in technology in the various areas that it regulates.

In the federal government, the historic approach to developing regulation around new technologies has been for regulators to conceptualize new regulations and spend months or years drafting rules for public comment. Next, months or years are spent obtaining comments and then those often-voluminous comments are examined, and proposed rules and regulations are revised. Adaptive approaches, by contrast, rely on a more iterative approach that allows for a shorter process and gets significant input from business, citizens and others into the process earlier. The National Highway Traffic Safety Administration (NHTSA)'s 2016 Federal Automated Vehicles Policy offers an example. By taking an iterative approach in designing policy for autonomous vehicles, the NHTSA responded to new data and

technologies to make significant revisions to its initial policy of 2017. This adaptive approach also makes frequent use of "soft law" mechanisms such as informal guidance, best-practice guidance, codes of conduct, and third-party certification and accreditation. These mechanisms are proving useful as new technologies first emerge and rapidly evolve in limited usage. While the NRC is inclusive of stakeholder input for revising regulations, it could consider such mechanisms, which allow for faster feedback loops.

Regulatory Sandboxes

An accelerating trend for regulating agencies globally has been the creation of accelerators and "sandboxes", in which they work with research institutions, businesses, and entrepreneurs to experiment with new technologies in environments that enable innovation. Sandboxes are controlled environments that that allow for approaches to be tested without having to follow all the standard regulations. Financial technologies, like cryptocurrencies, have been an area that has created sandboxes in multiple countries. Regulators of automated vehicles and unmanned aerial vehicles (UAVs) have also created sandboxes in the United States. These are designed to test the use of technologies in a safe and limited environment while they are in early development or deployment.

Clearly, much of what the NRC regulates does not lend itself to a sandbox approach. Detractors of a sandbox approach point to concerns about the safety of sandboxes involving the public and the risk of regulators getting too close to industry members and becoming committed to a technology's success. Opportunities may exist, however, in lower risk aspects of innovation.

Performance-Based Regulation

Performance-based or outcome-based regulation is an area in which the NRC has already been active, though it represents a significant break with past norms. Outcome-based or performance-based regulation specifies desired outcomes or performance objectives (depending on industry and application) rather than defining the way in which they must be achieved. A performance-based, technology-agnostic approach can allow for greater leeway for innovation by industry participants. Autonomous vehicles, where there are varying approaches to the technological challenges, is an area where it has been argued that performance-based regulation is needed at this early stage to ensure a level playing field.

In the context of the NRC's future, given the development and evolution of technology across all four scenarios, the NRC could consider increasingly adopting performance-based regulatory approaches to avoid stifling innovation while maintaining the NRC mission. This is particularly pertinent for the Nuclear Takes Off and Great Idea, But Not For U.S. scenarios, where the diversity of competing advanced reactor designs will stress a traditional technology-specific method of regulation.

Risk-Informed and Risk-Weighted Regulation

Risk-informed regulation focuses regulatory attention on those areas that represent the greatest risk in terms of probabilistic-weighted outcome. Risk-weighted regulation is similar in concept but slightly different in practice. Risk-weighted regulation utilizes a different regulatory process for different regulated enterprises depending on past performance or current characteristics and/or behaviors. The best-known example of a risk-weighted approach is the TSA PreCheck program, though a similar approach is being implemented in the FDA's Pre-Cert pilot program. Many believe that both risk-informed and risk-weighted approaches to regulation will offer even greater opportunities as more data becomes digitally available to regulators on an ongoing basis.

For the NRC, adopting risk-informed and risk weighted regulation was a common topic of discussion during both internal and external interviews for this report, suggesting the applicability of such approaches regardless of how the future unfolds is appropriate and necessary. Consensus leaned toward focusing NRC

resources where the risks and value added are higher, and work towards eliminating regulatory oversight in areas of low risk where it is not adding value. This allows the NRC and licensees to focus more effectively on its mission. Some regulations were put into place when the industry was less mature, and safety margins were estimated to be lower. Applying the same safety margins to newer, safer plant designs may not be appropriate given the tremendous track record of the nuclear industry in the U.S.

A recent EPRI report highlights the impressive track record for U.S. nuclear saying, "The most recent information available indicates that there are significant margins between the quantitative representations of the U.S. NRC's safety goals (that is, the quantitative health objectives – QHOs) and the subsidiary objectives widely used in considering risk-informed applications in the U.S. (that is, CDF and LERF)."[v]

The NRC should continue to explore risk-informed and risk-weighted approaches to regulation based on probability, past performance and current behaviors.

Collaborative Regulation

A common feature of many regulatory domains is an unwieldy patchwork of regulations across states and nations, leading to inefficiency in regulations. A recent global survey of more than 250 experts and leaders of financial institutions indicated that regulatory divergence, i.e., inconsistent regulations across different nations, costs financial institutions five to 10 percent of revenues or $780 billion annually. While the NRC is tasked with safety not industry financials, it should continue to consider a collaborative regulation approach in terms of involving and coordinating across all the organizations in the ecosystem in order to optimize outcomes and avoid unnecessary waste for both regulators and the nuclear industry. The NRC already focuses on creating an open, collaborative environment and working across boundaries, and regularly engages stakeholders in the ecosystem including foreign regulators and Agreement States. However, it is worth considering how the nature of collaboration might change depending on how the future unfolds. For example, in the Great Idea, But Not For U.S. and Gone with the Wind scenarios, the NRC faces a world in which the U.S. is no longer the technology leader in either nuclear reactor design and/or deployment. In such a world, the NRC may need to consider how it works with foreign regulators on accepting international standards or licensing from trusted international partners, or how it may increasingly need to work through the International Atomic Energy Agency (IAEA) to create international standards.

Governance

Governance is another area that may require enhancement for the future. Across the scenarios, the need for more expedited decision-making was raised repeatedly as an area that would have to be strengthened to ensure continued success in a changing future. A list of key elements of governance is shown in Table 1 below. While the NRC already has in place an existing decision-making framework with these elements, the interviews and scenario development process highlighted the possibility that the current governance structure and culture may create constraints on the NRC in the future. The NRC should consider whether the way it executes these elements of governance currently is appropriate for future scenarios. In particular, internal interviews noted the overly consensus-driven nature of decision-making and the tendency to pass decisions upwards, instead of being willing to make a decision. While these decision-making attributes are not surprising in a compliance and safety organization, and while some activities require a longer time frame due to statute or complexity, it was suggested by internal and external parties that there was room for many decisions to be expedited. Moreover, the increasing diversity of decisions that may need to be made when facing multiple new technologies in scenarios such as Nuclear Takes Off may necessitate faster decision-making processes. The NRC could also consider adopting a risk-informed and/or risk-weighted approach to decisions to push decision rights on specific issues (i.e., who has input,

who is to decide, who is to be informed) lower in the organization and accelerate decisions where appropriate, while maintaining or even enhancing predictability of decisions.

Table 1: Key Elements of Governance

Scope and Span	Areas and levels of the NRC that should be included in organizational governance
Decisions	Types of decisions that the NRC has to make
Decision authority and decision-making process	How decisions are made (consensus, majority rule, etc.) going forward, and who is involved in the decision-making process
Membership	Specific NRC individuals empowered to make decisions and who should be participating in the governance process for each area of the NRC
Calendar	Predictable, periodic (i.e., monthly, quarterly, annual, etc.) governance meetings aligned with the organization's/government's operating rhythms
Roles and responsibilities	Clear roles and responsibilities for each governance body to avoid any overlaps or gaps
Rules of engagement	Ground rules that are documented, and utilized to best enable effective and efficient NRC governance
Performance measures	Metrics to track and report NRC performance to best inform timely decision making

Culture

Culture is a system of values, beliefs, and behaviors that shapes how work gets done within an organization. It is getting renewed executive attention across government and the private sector for a variety of reasons. By 2030, the millennial generation, raised as digital natives, will not only be the mainstay of the workforce but will more than likely comprise the bulk of senior leadership, and are challenging established notions about employee/organizational identity. Beyond millennials, the talent that comprises an organization today is more diverse than ever before. Disparate expectations and work styles should be acknowledged. Culture initiatives are an ideal way to bring them together, harnessing their benefits, and aligning for the common good.

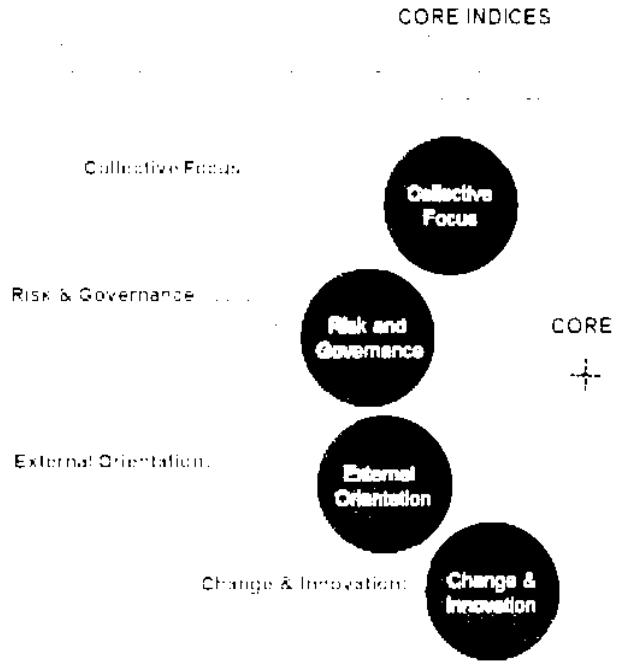
The need for NRC's culture to adapt to the potential environment in 2030 has already been recognized by the organization. As was emphasized in many of the interviews and working sessions, today's new hires will be tomorrow's NRC leaders. The challenge for organizations such as the NRC is further exacerbated with the competitive pressures on highly-specialized technical backgrounds, compensation limitations, regulatory compliance for the workforce (i.e., citizenship, clearances, certifications, etc.), and the notion that public service is not necessarily in vogue. A strong, sustainable culture that respects and inspires employees also helps create a powerful brand and can have positive effects on the NRC under any scenario. Engaged employees are more productive and loyal, and much more likely to recommend the organization to their talented friends.

The CulturePath™ methodology illustrates the many dimensions of organizational culture, as shown in Figure 4 below. [vi]While all areas were touched upon, the two most discussed areas for consideration for

action were Risk & Governance and Change & Innovation. In fact, it was suggested that the strong record of the NRC on the figure's right-hand side (the differentiating indices) may present a challenge when trying to make changes in areas on the left-hand side. The typical NRC officer has been at the NRC for a long time, and has a strong sense of commitment to the NRC and its mission. This strengthens *esprit de corps* but tends to reinforce the existing culture and behaviors. Discussions internally and externally suggested that this may mean the NRC, with regard to risk and in dealing with innovation, may be overly conservative as it looks ahead to change. While reducing risks related to nuclear safety is a key part of the NRC's mission, trying to become more risk-informed and responding to the needs of new technologies will require that the organization avoid the instinct to attempt to eliminate all risks. This will mean dealing with higher levels of ambiguity than some may feel is comfortable.

In addition, there was concern expressed that risk aversion extended beyond safety, leading to being overly cautious about what is said in public, having too many people review changes, or 'analysis paralysis' (doing too much analysis in fear of making a wrong decision). Communicating a shared view of the values, beliefs, and behaviors that need to be adopted to support more agile and adaptive performance without compromising the organization's existing commitment to safety will be a central challenge for leadership in the future.

Figure 4: The Culture Path™ Methodology Illustrates the Many Dimensions of Culture



Cultural change for the NRC will not be just about specifying the appropriate levels of risk. It is also about how well leadership encourages people to be flexible, willing, and adaptive to meet new challenges—regardless of the strategy selected or scenario(s) that present themselves. By considering moving the needle across the one or more of the eight areas listed above, the NRC could make its culture an even stronger mission asset that can help differentiate itself in attracting and retaining talent.

The NRC Office of the Executive Director for Operations (EDO) and senior program leaders can drive the capacity for change adoption throughout the organization by altering employee behavioral norms and reinforcing the appropriate cultural principles underlying the NRC. Although they will drive the initiatives

from the top, they will strengthen the program's bottom-up approach by understanding and addressing the issues, concerns, and barriers to change of those at the lower levels of the NRC organization. In addition, in thinking about how the NRC organizational culture (and with it, the NRC's approach to governance, human resources, and stakeholder outreach) should evolve, the NRC could consider further leveraging the younger generation within its staff. Working with and rewarding younger leadership candidates in creating the NRC of the future will not only capitalize on the strengths of younger NRC workers to position the NRC better to address the dynamic future, but also help to build ownership.

Potential actions relating to communicating and executing the path forward include:

- Characterize the NRC culture needed in the future
- Identify how efforts uphold underlying NRC values
- Capture the staff's emotional commitment to the change

As time progresses, potential actions needed for the changes to stick include:

- Create a plan to address challenges as the program matures beyond the initiative's stated period
- Embed the responsibility for driving the vision into day-to-day leadership objectives and plans
- Identify specific processes, roles, and structures that need to change
- Develop communication and engagement mechanisms to cascade the case for change across the organization
- Put an organizational infrastructure in place to support the desired future behaviors

In the end, more adaptive strategy, more responsive governance and a less risk averse culture that changes more readily (while maintaining the emphasis on safety and public health) may provide the essential organizational environment required to make all the other potential actions succeed.

With an aging workforce and a younger generation gaining a larger presence in the government, attracting and retaining top talent is critical to meeting the NRC's evolving mission. Among all four scenarios, there are certain common themes relating to the NRC workforce. There is clear recognition that the NRC workforce draws from much of the same pool of talent as the nuclear industry as a whole and needs to adapt its hiring practices to trends within the industry, as well as to trends in the federal workforce. The NRC workforce will also have to adapt to broader trends in the U.S. workforce, including technological and generational trends; by 2030, for example, Gen Xers will start to retire, and many millennials will be occupying positions of senior leadership across organizations. This will affect how the NRC thinks about retention, including rethinking the traditional NRC career model.

Another common theme across the scenarios is how the NRC will develop and retain the skillsets it needs, even as the specific skillsets needed vary across scenarios. This includes building on the work that the NRC has done to adapt to trends in training and knowledge management for the NRC permanent staff. It also includes examining other options besides permanent staff that the NRC can use to augment staff capabilities such as technology (discussed in greater depth in the Increasing Efficiency Through Technology section) or contracting.

Along those themes, a number of specific actions that may help the NRC prepare for human capital changes are: (1) Hiring; (2) Retention and Career Model; (3) Performance Management; and (4) Training and Knowledge Management.

Hiring

Each of the scenarios presents challenges in hiring. In the two scenarios with high growth in demand for nuclear power in the U.S., the NRC finds itself needing more staff, but facing challenges in hiring staff. In Nuclear Takes Off it will need to compete for talent with the nuclear industry itself. In What's Old is New Again, with the nuclear industry continuing to face perception issues in growing its talent pool and engineering students preferring to enter the renewable energy industry, the NRC may need to look at mid-career hires from within the nuclear industry. Meanwhile, in Gone with the Wind, the NRC's need for staff will decline after an initial wave of decommissioning, and the NRC will need to plan on how to keep attracting the hires it still needs for an industry perceived to be on the decline.

In each of the scenarios, the NRC will also need to plan for a future in which it could be looking for candidates with a more diverse range of skill sets and backgrounds, include in many cases skills outside nuclear engineering or even the physical sciences. In the two scenarios with disruptive innovations in technology (Nuclear Takes Off and Great Idea, But Not for U.S), there is a need to recruit staff who have skills that are not specific to the nuclear industry, but that understand technologies that NRC licensees are using such as new construction techniques or advanced modelling and simulation. In Nuclear Takes Off, for example, the NRC may need to hire people with experience familiar with large-scale 3-D printing and carbon fiber construction materials in order to be able to regulate the adoption of such technologies by licensees. Similarly, in a high-investment, high-innovation future the nuclear industry may pursue greater use of AI and advanced modelling and simulation in design and potentially in operation. Individuals with skills that are applicable across many industries are likely to be in great demand. In Gone with the Wind, the growth in new uses of nuclear radioisotopes may require the NRC to increase its hiring of staff with radiological health sciences backgrounds. In Great Idea, But Not for U.S, even as the NRC needs fewer staff, it will need to hire candidates to address the greater expectations of its international role under that scenario, including skills such as international experience or language abilities. As it becomes clearer how the future is unfolding, the NRC could consider how to feed in information about the new skills anticipated into the enhanced strategic workforce planning (eSWP) process that the NRC implemented in 2018 for

analytics-driven workforce planning.

Across all four scenarios, the NRC could consider how it targets candidates from a more diverse set of backgrounds, moving beyond recruiting from engineering/physical sciences programs in universities and nuclear-trained navy staff. Historically, the NRC has not had difficulty attracting candidates for employment and has a strong brand as an engaging place to work. However, as scenarios unfold, it could consider defining a value proposition that can attract new hires in the context of the external environment. For example, in What's Old is New Again, the need for expertise in large light-water reactor technology and the lack of may require shifting its recruiting and branding focus towards mid-career staff already in the nuclear industry. The NRC could also consider creative marketing strategies targeted at their candidates in order to attract a diverse array of new hires.

Retention and Career Model

Another common action that the NRC should consider taking across different scenarios is enhancing the employee experience. Retention of staff will depend on having engaged staff (engaged employees are four times more likely to stay in their jobs). Thus far, the NRC has performed credibly on the Federal Employee Viewpoint Survey (FEVS). To prepare for the future it may need to think about mapping and redesigning the employee experience for a changing workforce end to end – from sourcing and recruitment to onboarding and retirement – and to consider how to embed the employee experience throughout the organization with a sense of shared ownership for ensuring a positive experience. This includes the physical experience (real estate, facilities, collaborative workspaces, flexible work environment), the organizational experience (people, values, management style, communications, rewards), and the digital experience (digital capabilities and processes, cyber security, and the ability to use digital technologies work remotely). The specifics of the "right" physical employee experience will vary according to the scenario: for example, the larger NRC staff in the What's Old is New Again will require greater real estate facilities, whereas the Gone with the Wind scenario may require rethinking the current regional structure and consolidating where NRC staff are located. However, in all scenarios, a workforce that will be increasingly digital is likely to demand a more digital work experience, and the NRC could consider leveraging digital platforms that communicate the way employees do in their personal lives – online, in real time, and via multiple channels – and that enable working remotely. As the NRC considers redesigning the employee experience, important principles to bear in mind are employee-centered design (i.e., a mindset and discipline that puts the employee, rather than work processes, at the center of the employee experience), as well as openness and sharing information early to build foundational trust.

Regardless of the scenario, people, particularly young talent, are much less likely to expect or want to stay in the NRC for their entire career but will want to have meaningful impact and career growth during their time at the NRC. This reflects societal trends in jobs and careers.[vii] The NRC may need to ensure that it offers employees a job path for these changing preferences. Options that it can plan for include: short, high-impact project opportunities; exposure to wide range of distinct types of NRC work early in careers; and international opportunities. Each of these options may be more valuable in certain scenarios over others, but it is a relatively low-cost to plan for these options.

An approach that has been successful in both government agencies and commercial organizations that the NRC could consider for planning the employee experience and employee career path is the creation of employee "personas", where the organization studies and listens to its employees to understand their needs, values, and behaviors, and segments them into a few distinct types.[viii] This can both enable the NRC to deliver a better employee experience tailored to the distinct personas and ensure that the organization has career paths to meet the needs of the different personas. At present, the career model in the NRC is based on a single, definitive prescribed career path, which may challenge the organization in futures where staff have different expectations as to what they want out of an NRC job or career.

Performance Management

The NRC could also consider how its performance management may need to adjust in the future to create accountability for the changes described earlier in this document, such as creating an agile organization, and enhancing strategy, governance, culture. This allows performance management to be a key driver in incentivizing exceptional work that drives the NRC's mission.

Across all scenarios the NRC may want to consider a more agile performance management process that will help managers and leaders see, recognize, and fuel performance regularly. Many organizations have radically changed the way they measure, evaluate, and recognize employee performance, moving away from traditional end-of-year appraisal towards real-time, ongoing performance management, blended between formal and informal regular "check-ins." Given the need for continuous learning across all scenarios, having regular performance management discussions that include discussions of capabilities and skills can help the NRC learn where to focus and what learning to adopt.

Training and Knowledge Management

Government training has traditionally focused on onboarding, fulfilling compliance requirements, and building skills for current roles. Indeed, the specific skillsets related to the technologies that NRC staff are expected to be familiar with will vary widely across the scenarios: advanced reactor technologies, for example, in the case of the Nuclear Takes Off and Great Idea, But Not for U.S. scenarios. Across all scenarios, training is a continuous process, not an episodic event; and as an organization-wide responsibility, not confined to Office of the Chief Human Capital Officer (OCHCO). To be able to meet the needs of its future workforce, the NRC should continue its shift from "training" to "learning" by utilizing competency models and offering more real-time learning experience building and career broadening opportunities that enable employees to explore new skills and interests while building capacity through the agency.

The NRC will also need to reconsider how it acquires and retains knowledge. Our experience shows that one trend in knowledge management is that employees will become increasingly digital and want to receive an experience akin to using search engines or social media when they search for information internally, ask colleagues a question, or share information. An action that is robust across all four scenarios is considering how the NRC should incorporate all the familiar digital capabilities (e.g., video, search, mobile, social) in its knowledge management system. The system needs to provide the employees one source of consistent and accessible organizational knowledge (e.g., experience, expertise, insights) that is properly managed, on top of consolidated information originally digitized and managed elsewhere, as well as the ability to collaborate and share knowledge.

While the need for digital workplace capabilities is robust across all the scenarios, the specific content, people, and culture that need to be engaged for knowledge management result in different options for actions under different scenarios. In What's Old is New Again, with existing nuclear plants receiving further license extensions, the NRC should consider how to retain or transfer the knowledge about these existing plants from a generation of retiring regulators. While capturing the knowledge of a retiring workforce is likely something that needs to be done across all four scenarios, the need to do so is particularly acute in What's Old is New Again. In Gone with the Wind and Great Idea, But Not for U.S., where significant technology development takes place outside the U.S., the NRC can consider options that increase its engagement with other countries' nuclear regulators.

The eSWP already looks at what functions need to be performed by its permanent staff, as opposed to achieved via temporary employees, contracting, or other contingent workforces. As the future unfolds, the NRC should consider using the eSWP process to regularly challenge and update the definitions of core functions. For example, in Gone with the Wind, budget pressures for a leaner staff means that even certain

functions currently considered core functions may have to be performed by contractors. In Nuclear Takes Off, conversely, the plethora of diverse nuclear technologies that the NRC will have to regulate may make it infeasible to keep a large staff that has knowledge of the entire gamut of available technologies. Either way, the NRC could consider preparing for the application of concepts such as leveraging contractors and contingent workforces.

All four scenarios envision a world where the technology available to support enterprises and regulators (e.g., data analytics, cognitive technologies such as artificial intelligence (AI) and robotic process automation (RPA)) continues to grow significantly in capability and applicability between the present day and 2030. These technologies often interplay with each other, and NRC staff should continually monitor if it would be possible to use technology to increase the efficiency of their own offices. Another key trend that applies across all scenarios is that as NRC staff encounter increasingly sophisticated digital capabilities in their personal lives, their expectations of the capabilities of the systems they encounter at work will also grow. The knowledge of technologies such as remote sensing/monitoring and modelling/simulation in use by licensees allow the NRC to provide effective oversight. Finally, cybersecurity and information classification play an important factor when considering leveraging these technologies to avoid the potential for adverse impacts to safety and security.

Data Analytics

In all four scenarios there is a need to enhance the NRC's efficiency to be prepared for the future environment. The NRC has been looking at text and data analytics to help more effectively utilize its extensive warehouse of documents, which are currently stored in scanned-document, non-machine-readable format. Where document query has been a labor-intensive process, advanced text and data analytics technology can better cluster knowledge products based on content and keywords, thereby making document query much more akin to a Google search, with search queries producing relevant and productive results. This would help the NRC more effectively utilize its own massive amount of data, predict trends, and identify potential risks in ways that were not previously practical through manual analysis. Data analytics tools could enhance the ability of the NRC to do documentation preparation during inspections, saving resources and time and preventing errors. Such tools can also be used by staff to analyze data about interactions with industry, drawing on internal and external sources such as research papers and media reports.

Greater efficiency may be needed to enable the NRC to take on a much wider range of licensing actions, as in Nuclear Takes Off's growth in the field of medical radioisotopes, or to enable the NRC to do more with less, as is the case in Gone with the Wind. Another common impact identified across all four scenarios is the need for risk-informed approaches to regulation and decision-making.

Advanced analytics may help the NRC examine data on NRC and stakeholder interactions for areas of potential improvement. Using neural networks, a type of AI that allows computers to recognize how concepts in a given piece of text relate to each other, such analysis could also bring to light overlapping and potentially conflicting regulations, the resolution of which holds the potential to reduce regulatory uncertainty and streamline NRC and stakeholder operations. Using analytics to check for conflicting regulations or regulatory responses may be particularly pertinent in scenarios such as Nuclear Takes Off and Great Idea, But Not for U.S. where there is disruptive growth in global innovation in nuclear reactor technology and a greater shift towards using performance-based licensing.

While these are only a few examples of applications of data analytics, data analytics technologies hold significant potential to be applied to a wide range of NRC's processes and activities.

Cognitive Technologies

Cognitive technologies, often referred to as AI, are technologies that can perform and/or augment tasks, help better inform decisions, and accomplish objectives that have traditionally required human intelligence, such as planning, reasoning from partial or uncertain information, and learning. They include a variety of new and improved capabilities including RPA[ix], rule-based systems (to capture expert

knowledge), speech recognition, machine translation, computer vision, machine learning, and natural language processing.[x] Separately and in concert, these technologies are experiencing rapid expansion in industry and government applications. From an industry compliance, regulatory oversight, rulemaking, or a license application review point of view, cognitive technologies hold the potential to enhance the NRC's process performance. For example, by the NRC's own estimation, changing regulations can take up to five years; the NRC can examine and identify where its workflow processes can be streamlined and improved by software robots or AI-augmented workers.

Combining data analytics with cognitive technologies also holds the potential to identify potential risks, further enhancing the NRC's capabilities in risk-informed and risk-weighted decision-making. As technologies evolve between the present day and 2030, the NRC could consider monitoring developments in the evolution of cognitive technologies and their applicability to the NRC's own processes, to allow it to take advantage of the technology's ability to efficiently and effectively support the NRC in its mission. For example, the NRC could use advanced analytics and machine learning to analyze long-term data trends to identify data that could be early signals of potential safety issues. This could enable predictive analytics for early detection of potential issues at specific licensees long before they become serious and inform the production of a set of action items to be followed by these licensees. This shift from one-size-fits-all regulation to a data-driven, segmented approach to licensees could be especially relevant in scenarios with reduced NRC resources such as Gone with the Wind and Great Idea, But Not for U.S.

Technologies That Enable Digital Approaches to Regulation

In all scenarios save for Gone with the Wind, digital I&C is being increasingly implemented in reactors, including digital sensors, control systems, and monitoring. With its digital nature, this technology has the ability to generate and communicate greater streams of data and take advantage of efficiencies and features such as automatic failover based on self-diagnostics. Licensees will likely increasingly use of digital I&C and autonomous remote sensors, connected via the Internet of Things (IoT), to generate data and improve their own performance. The NRC should continue adapting its regulatory frameworks for the rapidly changing nature of digital technology and look for ways to better leverage the greater volumes of data being generated by licensees for licensing and oversight in a manner that enhances safety and increases its efficiency. Knowledge of emerging technologies leveraged by licensees plays a key role in effective oversight.

In addition to enabling the NRC to be innovative in its routine oversight and licensing roles, digital I&C technologies continue to support the NRC in emergency event response situations. Time is of critical importance during a nuclear safety incident and given the serious health and safety concerns related to information collection during a nuclear safety incident, minimizing information gaps and asymmetries is critical. With the ability to obtain increasing amounts of data from licensees' digital I&C and IoT-enabled sensors, the NRC is able to more quickly aggregate and analyze information about events, helping responders better identify incidents, decide how to respond, and communicate decisions (and critical actions) to those involved. As digital technology continues to evolve, NRC knowledge of licensee technology and information gathering techniques will need to keep pace in maintaining effective and efficient oversight.

The NRC is part of a broad ecosystem in the nuclear industry that includes government entities (international, federal, state, local, and tribal), private sector organizations, academia, and volunteer organizations. Across all four scenarios, stakeholder engagement will remain an essential element and a robust strategy in the future as the NRC interacts with a more diverse set of stakeholders, and engages them through new communication platforms, as stakeholders become partners and advocates for change as the industry deals with uncertainty. The NRC will also have to continue to focus on being transparent as it faces greater calls for more openness. Combined efforts among stakeholders in future scenarios will be essential to help find innovative solutions, tackle common challenges, and enhance the NRC's ability to fulfill its mission and operate efficiently.

In order to build effective stakeholder engagement, the NRC should continue to:

- Bring in external stakeholders' viewpoints to validate and refine their strategy
- Include the downstream impacts (e.g., on licensees and local communities) of shifts when soliciting inputs
- Engage formal and informal external influencers in designing and communicating solutions
- Gain buy-in and support of Congressional overseers, the Office of Management and Budget (OMB), U.S. Government Accountability Office (GAO), industry groups, think tanks, non-governmental organizations (NGOs), etc.

Today, the NRC has a strong process of broad stakeholder engagement, through various communications, over 1,000 public meetings annually across the U.S., participation in social media, and providing access to a vast document repository which includes government files and correspondence. In the future scenarios identified, the NRC can build on that strong process by adapting stakeholder engagement to the stakeholders of 2030 and beyond, both in terms of reaching future stakeholders on new topics to engage on and adapting the methods of communications.

Diverse Stakeholders

In the future scenarios identified, the set of external stakeholders that the NRC will have to interact with in 2030 and beyond is more diverse than the present day, although the profile of those external stakeholders will vary across each scenario. In Nuclear Takes Off and Great Idea, But Not for U.S, the nuclear industry evolves as smaller, safer reactors enter the market. This will present opportunities for the NRC to engage stakeholders on topics concerning new reactor technology. In scenarios where there are public concerns over nuclear reactor safety or nuclear waste disposal, such as in Gone with the Wind and Great Idea, But Not for U.S, the NRC may have to further engage stakeholders including lawmakers, NGOs, local communities, and native tribes on public safety issues to address concerns over reactors and nuclear waste management.

Internal and external interviews suggested that the NRC might be sometimes overly cautious in certain aspects of engaging stakeholders to avoid the appearance of being too close to licensees. This approach may be tested by the scenarios with disruptive growth in technology, such as Nuclear Takes Off and Great Idea, But Not for U.S., where the NRC would need to understand leading technologies. In the Nuclear Takes Off scenario, the nuclear industry benefits from increased innovation in nuclear reactor technology, spurred on in part by advancements from entrepreneurs in Silicon Valley. The NRC should thus consider how it engages with new licensees with more entrepreneurial business cultures and business models that differ from its traditional licensee base, understand how to work closely and in conjunction with Silicon Valley and other new entrants to educate them on NRC regulations and licensing requirements, and incorporate insights gleaned into its regulations and policies. This will present an opportunity for the NRC

to integrate industry-leading practices into NRC operations, especially in areas such as big data and analytics, cybersecurity, and artificial intelligence.

Furthermore, in most of the scenarios, there is a greater call for cooperation with international entities and agencies. In the Great Idea, But Not for U.S. scenario, the need for harmonized international standards and better aligned regulations will encourage the NRC to interact and partner even more with foreign governments. This will provide an opportunity to further identify efficiencies, reduce costs and share best practices. By sharing best practices, the NRC and foreign agencies will be able to align and on industry-leading practices, especially in areas such as data sharing and cybersecurity. By expanding partnerships with foreign governments and international organizations, the NRC will also be better placed to respond to changes in the global nuclear environment, and better coordinate in event response to unforeseen situations.

Openness and Transparency

Communication, and indeed over-communication, is an essential element of any change management strategy. In the future, as decisions and changes are made, the NRC would benefit from making sure stakeholders are clearly aware of the rationale behind these decisions and solicit their support. This is also important to make sure stakeholders feel they are engaged and valued, and to avoid any misperceptions. Today, the NRC has taken many steps to increase transparency, including providing licensees with greater visibility into its fee structure and licensing processes. In future scenarios such as Nuclear Takes Off, as the NRC interfaces with increased stakeholders, it will continue to face calls for greater openness and transparency.

Digital Channels of Communication

Looking to the future across all scenarios, the NRC might consider increasing its digital communications, leveraging the dominant social media platforms of the future to expand their reach and increase direct interactions with stakeholders, including international entities, entrepreneurs, universities, and the general public. Digital engagement would also serve as a tool to not only engage stakeholders and solicit feedback, but also to market the NRC to prospective candidates and this attract talent, including a younger workforce. The NRC could also invest more in leveraging digital learning platforms to educate new external stakeholders on regulations and licensing requirements. This would provide a low-cost option to help these stakeholders better understand licensing requirements and more easily comply with regulations. Lastly, the NRC could also leverage ethnographic researchers to help identify unnecessary delays and pain points with their stakeholders to help streamline processes and regulations.

Appendix A: Four Futures for the NRC External Environment

High

What's Old is New Again

Energy demand is rising as the U.S. economy continues to grow while advances in energy efficiency have plateaued. Concerns over climate change and fracking accidents have led to an increased focus on clean energy. While renewable energy is competitive, nuclear power is needed to meet the growing demand. Demand for nuclear from abroad has contributed to the growth of new designs in SMRs, but beyond modularity, nuclear reactor technology has only experienced incremental innovations. However, while these innovations are not disruptive, the improvements in construction combined with carbon taxes and government subsidies have made large light water reactors more economically viable to build and operate, and existing LWR facilities are seeking to extend their productive lives. To deal with the spent fuel, two CISFs have been licensed. Although the industry is on an upswing, attracting younger workers to the nuclear industry is a challenge.

Nuclear Takes Off

Energy demand in the U.S. and globally is skyrocketing, in large part due to the rapid electrification of the vehicle fleet. Meanwhile, concerns over climate change have led to a renewed focus on clean energy sources. Renewable energy is cost competitive, but nuclear power is also needed to meet U.S. demand. Growing global use and supply of nuclear power has led to greater harmonization of regulations internationally. Small modular reactors are prevalent, and advanced non-light water reactor technology has improved dramatically, as has micro-reactor technology. A deep geological repository receives funding from Congress, alleviating concerns over the increased waste from increased nuclear activities. The demand for nuclear power has led to significant competition to employ and retain those with nuclear training or experience.

Incremental innovation only

Disruptive & incremental innovation

U.S. Nuclear Power Demand*

Global Reactor Innovation**

Gone with the Wind

The economy continues to grow slowly, and U.S. energy demand decreases due to increased energy efficiency in use, transmission and storage, and a continued shift to less energy-intensive industries. With newer battery technology solving the intermittency problem of iteratively cheaper wind and solar generators, public opinion and U.S. policy has made a collective decision to shift toward renewables. Despite an increased environmental focus among decision makers, low-cost gas remains a major element in the energy mix while nuclear' s share of electricity generation declines as the public and national leaders continue to perceive risks in nuclear energy. Hoped for breakthroughs in advanced reactor performance and nuclear plant construction costs have not materialized. New nuclear plants are being built overseas, but in the U.S., the nuclear power industry is contracting and continues to decommission non-competitive reactors. New applications and domestic producers in nuclear medicine provide the largest remaining growth opportunity for the U.S. nuclear industry.

Great Idea, But Not for U.S.

Energy demand in the U.S. has plateaued while globally energy demand is still soaring. Concerns over climate change have led to booming demand in renewable energy and carbon capture and storage, but a wary public does not perceive nuclear power as necessary for climate action. Reactor technology has advanced dramatically, and the U.S. continues to be in the forefront of technology development, but new plant construction is focused in the developing world. A handful of high-profile safety and security incidents at international nuclear plants has further affected the U.S. public acceptance of nuclear. The global demand for nuclear has led to a pivot of the U.S. nuclear industry away from U.S. construction toward a focus on exporting technology and expertise internationally.

Low

Full axis labels:
** Overall U.S. demand for nuclear power generation capacity*
*** Innovation in nuclear reactors globally*

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U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Scenarios: Signposts and Markers

January 11, 2019

Recap: Four Futures for the NRC

What's Old is New Again

Energy demand is rising as the U.S. economy continues to grow while advances in energy efficiency have plateaued. Concerns over climate change and fracking accidents have led to an increased focus on clean energy. While renewable energy is competitive, nuclear power is needed to meet the growing demand. Demand for nuclear from abroad has contributed to the growth of new designs in SMRs, but beyond modularity, nuclear reactor technology has only experienced incremental innovations. However, while these innovations are not disruptive, the improvements in construction combined with carbon taxes and government subsidies have made large light water reactors more economically viable to build and operate, and existing LWR facilities are seeking to extend their productive lives. To deal with the spent fuel, two CISFs have been licensed. Although the industry is on an upswing, attracting younger workers to the nuclear industry is a challenge.

Nuclear Nirvana

Energy demand in the U.S. and globally is skyrocketing, in large part due to the rapid electrification of the vehicle fleet. Meanwhile, concerns over climate change have led to a renewed focus on clean energy sources. Renewable energy is cost competitive, but nuclear power is also needed to meet U.S. demand. Growing global use and supply of nuclear power has led to greater harmonization of regulations internationally. Small modular reactors are prevalent, and advanced non-light water reactor technology has improved dramatically, as has micro-reactor technology. A deep geological repository receives funding from Congress, alleviating concerns over the increased waste from increased nuclear activities. The demand for nuclear power has led to significant competition to employ and retain those with nuclear training or experience.

High

Incremental innovation only

Disruptive & incremental innovation

Innovation in Nuclear Reactors Globally

U.S. Nuclear Power Demand*

Gone With the Wind

The economy continues to grow slowly, but U.S. energy demand decreases due to increased energy efficiency in use, transmission and storage, and a continued shift to less energy-intensive industries. With newer battery technology solving the intermittency problem of iteratively cheaper wind and solar generators, public opinion and U.S. policy has made a collective decision to shift toward renewables. Despite an increased environmental focus among decision makers, low-cost gas remains a major element in the energy mix while nuclear's share of electricity generation declines as the public and national leaders continue to perceive risks in nuclear energy. Hoped for breakthroughs in advanced reactor performance and nuclear plant construction costs have not materialized. New nuclear plants are being built overseas, but in the U.S., the nuclear power industry is contracting and continues to decommission non-competitive reactors. New applications and domestic producers in nuclear medicine provide the largest remaining growth opportunity for the U.S. nuclear industry.

Great Idea, But Not in my Backyard

Energy demand in the U.S. has plateaued while globally energy demand is still soaring. Concerns over climate change have led to booming demand in renewable energy and carbon capture and storage, but the public does not perceive nuclear power as necessary for climate action, and nuclear's share of U.S. energy generation declines. A few high-profile incidents at international nuclear plants have further affected the U.S. public acceptance of nuclear technology, even though there was little actual threat to safety and security. Reactor technology has advanced dramatically, and the U.S. continues to be in the forefront of technology development. New plant construction is focused in the developing world, where U.S. firms are in keen competition with foreign state-owned enterprises. The global demand for nuclear has led to a pivot of the U.S. nuclear industry away from domestic construction toward exporting technology and expertise internationally.

Low

*Full label: Overall U.S. demand for nuclear power generation capacity

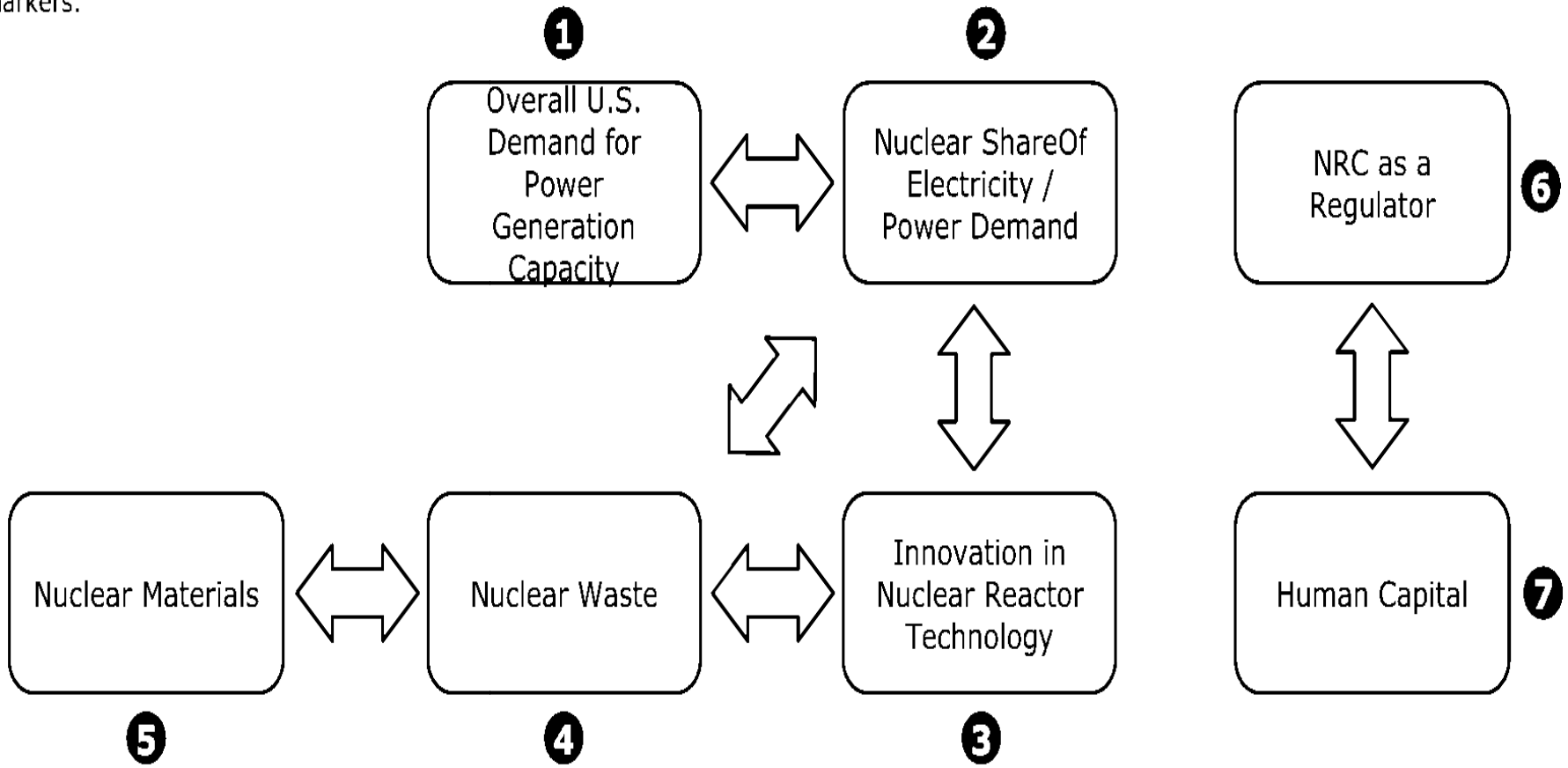
Scenarios: Signposts and Markers

	Impact	Action Options
How will the future unfold?	What are the impacts to the NRC?	What will NRC need to do to prepare for that impact?

Signposts and markers are key developments and dynamics that are tracked to identify how the future seems to be unfolding in the real world.Signposts are precursors towards the direction of the future. They reflect the broader conditions in the environment being monitored.Markers are the "trail markers" that hint at which signpost, and ultimately which future, you might be moving toward.They differ from key performance indicators in that they are about monitoring the external environment, while KPIs are about tracking internal performanceThere will often be incremental changes in the markers being measured; what can signal moving towards a particular future is when the markers show significant or disruptive changeMarkers can be quantitative (including compelling data ratios) or qualitativeThe specific metrics are the unit used to measure that marker

Tracking signposts and markers

Based on research, interviews, and input from the NRC meeting of December 11, we have identified 7 key areas for tracking signposts and markers.



AssumptionsThe suggested markers in the following slides were developed with the assumption that there are already key figures and indicators that the NRC is already trackingThe markers are developed based on publicly available data. Confidential information that the NRC may receive (e.g. DHS data on the overall threat environment) might further illuminate how the future might unfold, but this is beyond the scope of this projectWe have created both suggested direct markers as well as leading markers. Direct markers are direct measures of whether the NRC is at/approaching a signpost. Leading markers are measures that can indicate that the external environment is heading towards a particular direction at an earlier stage, but with the possible tradeoff of being a weaker or less certain signal of that direction

Signposts and Markers: Overall U.S. demand for power generation capacity

How **large is the overall size of the U.S. economy** and have there been significant changes in the GDP growth trajectory?	• Size of economy (Current GDP: $19.39 trillion,)	• Economic growth (GDP growth rate,)
Have electric vehicles, desalination, or other new energy-intensive industrial processes caused demand for power generation to grow exponentially?	• Overall demand for electricity generation (Current level of electricity production: 3723 TWh, EIA)Growth of electric vehicle fleet (sales of electric vehicles, DOE Alternative Fuels Data Center)Planning permits for desalination and reverse osmosis water treatment plants	• Stated commitments of major car manufacturers regarding electric vehicle production (News reports)Battery technology for vehicles (Energy density)Cost of desalination (Cost per 1,000 U.S. gallons, particularly if it goes below $2/1,000 U.S. gallons)Reports on growth in desalination and other energy-intensive industrial processes (News reports)
Have there been any **major gains in energy efficiency**, whether in industry, buildings, or appliances/lighting?	• Efficiency of power generation (transmission loss, IEA data)Energy intensity of economy (BTU/$ GDP, DOE)Energy efficiency of buildingsEnergy efficiency of appliances/lighting (Efficiency of lighting and household "white goods")	• Developments in superconductivityBreakthrough energy efficiency technology similar to the switch to LED lighting (News reports)Increase in demand-response programs, including use of smart metering and smart office/home technology to manage energy use
Are there **any major increases in imports of electricity** from Canada?	• Imported electricity from Canada (2017 net electricity imported from Canada: 62 TWh; ,)	

Signposts and Markers: Nuclear Share Of Electricity / Power Demand (1 of 2)

Has U.S. public acceptance of nuclear power changed significantly (either more or less accepting)?	• Public attitudes to nuclear energy (NEI National Public Opinion Survey on Nuclear Energy,)	• Public attitudes to climate change (Annual Gallup environmental survey, Gallup)Public attitudes to the environment (Annual Gallup environmental survey, Gallup)Major nuclear-related events/accidents in the U.S. (NRC data)Major nuclear-related events/accidents outside the U.S. (NRC data)Major safety events/accidents related to non-nuclear sources of power, especially fracking
Has the **level of safety and/or security of nuclear power** in the U.S. changed significantly?	• Safety or security events (Volume of events reported, NRC data)	• Pre-application meetings with regards to advanced non-light water reactors in the U.S., on the assumption that advanced reactors are likely to feature increased safety and security (NRC data)
How **feasible and reliable is large-scale deployment of renewable energy**?	• Reliability of solar / onshore wind / offshore wind (Overall grid reliability compared to percentage of renewable resources, NERC)	• Feasibility of storage technology (Degree to which electric storage resources are participating annually in organized wholesale electricity markets,)
How **affordable is nuclear energy relative to other sources of energy**, both in terms of capex (cost of construction of power plants) and opex (cost of fuel, other costs of operations, subsidies, carbon taxes, other taxes that affect different sources differently)?	• Overall cost of energy production (Levelized cost of production)Construction and financing costs (interest rates, Federal Reserve)Operating expenses (mills per kWh, EIA)Fuel costs (natural gas spot prices, crude oil prices, cost of uranium) Federal and state subsidies and taxes, including carbon taxes, and how they affect different energy sources	• Forward prices (natural gas spot prices, crude oil prices, cost of uranium) Federal and state policy statements on energy subsidies and taxes (News reports)Public announcements by power generation companies on types of plants being constructedFinancial health of nuclear power companies based on public dataInvestments in nuclear power generation capacity vs competing energy sources

Signposts and Markers: Nuclear Share Of Electricity / Power Demand (2 of 2)

How **centralized or decentralized is energy production**?	• Growth of prosumers (Annual estimates of capacity and generation for small-scale (<1MW) solar PV systems,)	• Federal and state policy statements on energy grid (News reports)
Are clean energy policies being enacted and is nuclear power considered as part of clean energy?	• Creation of CO2 emission caps (total emissions covered by emission limits or cap-and-trade systems)Inclusion or exclusion of nuclear power into state clean energy portfolio standardsRestrictions on fossil fuel production/generation (laws at state and federal level to restrict production/generation)	• Federal and state policy statements on emission limitsFederal and state policy statements on clean/renewable energy portfolio standardsMajor safety events/accidents related to non-nuclear sources of power, especially fracking
What is the federal government energy policy (both formal and de facto) on reliability/resilience of power sources, research into different power sources, and waste storage?	• Introduction of reliability and resilience policies (U.S. energy policy)Amount of research into nuclear energy vs other energy sources (U.S. government R&D dollars spent on nuclear, renewable energy and battery technology, and other sources)Waste storage policy	• Federal and state energy policy statements, particularly statements reflecting a shift away from laissez-faire energy market policy (e.g. policies introducing minimum levels or percentages of energy supply that is nuclear in order to maintain reliability of baseload)Congressional statements on energy policyReports on public attitudes to waste storage (e.g. if surveys are commissioned)

Signposts and Markers: Innovation in Nuclear Reactors Globally

What is the level of innovation in reactor design? i.e. How widely deployed are Gen IV/advanced non-light water reactors	• Pre-application meetings with regards to advanced non-light water reactors in the U.S.License applications for advanced non-light water reactors globally	• Externally stated strategies of firms (power generation companies, nuclear reactor design firms etc.)Developments by DoD and other government designers of nuclear reactorsAnnouncements by nation-states and state-owned enterprises (Info from Multinational Design Evaluation Program)
What are the **sizes of reactors?** i.e. What is the level of deployment of large LWRs compared to small modular reactors and micro-reactors?	• Pre-application meetings with regards to small modular reactors (both U.S. and global)Pre-application meetings with regards to micro-reactors (both U.S. and global)	• Externally stated strategies of major firms (power generation companies, nuclear reactor design firms etc.)Developments by DoD and other government designers of nuclear reactorsAnnouncements by nation-states and state-owned enterprises
What is the **level of innovation in reactor construction**?	• Speed of constructionCost of constructionChanges in materials used and construction techniques	• Amendment reviews for first-of-a-kind technology
What is the **level of innovation in reactor operations**?	• Innovations in uses of technology such as digital I&C, AI within reactors, accident-tolerant fuels	
Are there **major new non-electricity uses** for nuclear reactors?	• Pre-application meetings with regards to reactors that use nuclear for process heat e.g. for desalination	
Is there significant interest in **research into nuclear energy**?	• Levels of nuclear R&D funding from the federal governmentLevels of nuclear R&D funding by foreign governmentsLevels of nuclear R&D funding by commercial firms	

Signposts and Markers: Decommissioning and Waste

What is the **quantity of low-level and high-level waste** being produced?	• Spent fuel (Annual commercial spent fuel discharges and burnup, EIA)Number of reactorsReactor technologyAging of reactorsNumber of reactors being decommissioned	
Will **storage facilities receive funding**?	• Congressional approval for funding for deep geological disposal repositoryCongressional approval for funding for CISFs	• Local and national support / opposition to storage (see below)
Are **there major developments in decommissioning and storage technology**?	• Advancements in canister technologyAdvancements in fuel managementAdvancements in transportation technology	• Research in storage technology including canister technology, fuel management, transportation technology (R&D funding for storage technology, Spent Fuel and Waste Science and Technology Storage and Transportation R&D Campaign)External announcements by firms including 3rd party decommissioning firms that signal changes in efficiency of decommissioning
Is there **significant support or opposition for nuclear waste storage**?	• High impact events (media coverage, survey data on public attitudes following high-impact events)State/local laws passed relating to nuclear wasteFederal laws passed relating to nuclear wasteSurvey data on public attitudes in specific states	• Policy statements related to nuclear waste by Congress, federal agencies and state governments

Signposts and Markers: Nuclear Materials and Fuel Cycle

Are there significant **changes to the front end of the fuel cycle**, including uranium recovery and fuel fabrication processes?	• Pre-application meetings for new uranium recovery facilities, expansions, restarts, and renewals	
Is the **overall demand for nuclear materials** significantly increasing/decreasing?	• Pre-application meetings for new uranium recovery facilities, expansions, restarts, and renewals	
Is the **use of nuclear radioisotopes for medical and industrial purposes** significantly increasing/decreasing?	• Size of the medical radioisotope industry ($)Size of the industrial radioisotope industry ($)Materials licensing actions received	• Commercial firm or researcher announcements of new diagnostic and therapeutic uses of medical radioisotopesCommercial firm or researcher announcements of new industrial uses of radioisotopes
What are the alternatives to nuclear materials?	• Success of commercial substitutes to nuclear materials	• Policy statements by government security agencies (e.g. NNSA) on proliferation concernsPolicy statements by government security agencies on developing alternatives to nuclear materialsPublic attitudes to using nuclear materials for medical / industrial purposes
Where are nuclear materials produced globally?	• Development of nuclear materials production (Quantity and ratio of nuclear materials production in US and the rest of the world)	

Signposts and Markers: NRC as a Regulator

Openness: are the **stakeholders of the NRC changing** in terms of where they are located and how the NRC can reach out to them?	• Regional distribution of NRC licenseesDigital public outreach (social media engagement metrics)	
Efficiency: Are the business model of **licensees becoming different from the "traditional" licensees**?	• Pre-application meetings that signal new business models for potential NRC licensees	• Adoption of public-private partnerships by other peer federal agencies
Efficiency: Are **approaches to regulation evolving across the government** that could significantly enhance efficiency? (e.g. use of performance-based regulation, risk-weighted regulation; use of conceptual design to provide feedback on reactor designs)	• Adoption of new regulatory approaches by other peer federal agenciesAdoption of new regulatory approaches by other nuclear regulators globally	
Efficiency: What are the general political trends regarding regulation and the role of government?	• Political climate towards regulationBudgetary environment for government	• Administration policy statementsCongressional statementsLegislation
Efficiency: Is the **technology needed for or used by NRC for its functions (particularly regulation and oversight) changing**?	• Availability of big data analytics and digital tools for augmenting decision-making such as AIAvailability of digital oversight tools such as modeling / simulation, augmented reality that could complement or physical inspection	
Are there major developments that lead to **changing expectations of NRC's international role and activities**, including the NRC's role in technical assistance for other regulators, cooperation and harmonization on international standards?	• Shift towards global focus of NRC licensees (international investment by licensees)International demand for nuclear power (number and locations of reactors being planned globally, total number of countries with nuclear reactors, total capacity of reactors outside the U.S.)Technological leadership of U.S. in nuclear power vs others (Number and locations of advanced reactors and SMRs in U.S. compared to rest of world)	• Nuclear investment by foreign entities (private and public)Announcements by nation-states and state-owned enterprises

Signposts and Markers: Human Capital

Has the hiring environment changed significantly?	• Ability to attract young talent to the nuclear industry as a whole (Demographic data on the nuclear industry, including average age of the nuclear industry workforce)Demographics of the broader U.S. government workforce (Average age of U.S. government workforce)Competition for engineering talent in the energy industry (Number of nuclear engineer jobs, salary for nuclear engineers, salary for engineers in renewable and natural gas industries; see BLS data)	• Pipeline of nuclear engineers (number of schools with nuclear-related programs, enrollment in STEM programs at undergraduate and graduate school levels)Starting salaries for engineers in nuclear, renewable, and natural gas industries
Have expectations for what an **NRC career path** looks like changed significantly?	• Skillsets needed for NRC careersExpectations of career model and time spent at NRC (Average length of employment at an organization for a nuclear engineer, average length of employment for millennials and Gen Z)Development of IT innovations that can support digital, flexible workforce	
Has the **training environment** changed significantly?	• Developments in training approachesDevelopments in training delivery technology	
Have there been significant developments in ways to **augment the workforce** beyond the traditional NRC full-time staffing model?	• Adoption of workforce augmentation technology (e.g. AI, RPA) by nuclear industry, other peer federal agencies, and/or international nuclear regulatorsAbility to use contractors to perform previous "core" functions (Skillsets of contracting firms)Crowdsourcing technologies	

Downselection of Key Markers and Crosswalk

The long list of markers were downselected to a group of 100 key markers. These key markers were then crosswalked against the 4 scenarios

Number	Signpost	Marker	Type of Marker (Direct / Leading)	Metric	Source	Source link
1	How large is the overall size of the U.S. economy and have there been significant changes in the GDP growth trajectory?	Size of economy	Direct	GDP (Current GDP: $19.39trillion)	BEA	https://www.bea.gov/data/gdp/gross-domestic-product
7		Economic growth	Leading	GDP growth rate	BEA	https://www.bea.gov/data/gdp/gross-domestic-product

Notes on downselected markersGiven the range of different types of regulation that fall under the NRC's mission, we believe that 100 key markers is a reasonable number (for a typical commercial client with a much more narrow scope of work, we would recommend about 30 markers)The downselected markers represent a mix of qualitative and quantitative data. They have been chosen so that they are based on publicly available data or based on data that the NRC would have internally (e.g. pre-application meetings), and sourced accordingly.

See attached Excel spreadsheet for full list of markers and for crosswalk; Appendix also contains the crosswalk

Marker Monitoring – Best Practices

The following list contains best practices to be used in setting up a system for monitoring markers and identifying how the future may be unfolding

1 Ease of tracking

- Where possible, the metrics being used should be based on publicly available data and easy to compile

2 Regularity of tracking

- There should be a process of regular (ideally monthly) tracking of markers and reporting the markers to decision makers

3 Recognize disruption points

- Important to distinguish between incremental change, which often happens regardless of scenario, and disruptive changes (e.g., distinguishing between ordinary fluctuations in cost of renewable energy and step-changes in cost)

4 Identify threshold values

- For some markers, setting threshold points for the metrics that indicate disruption can make it easier to flag when disruptive changes have taken place (e.g. when the number of electric vehicles exceeds 1 million)

5 Use a blend of quantitative and qualitative markers

- A complete set of markers often includes both qualitative and quantitative markers. The earliest indications of movement towards a particular future is sometimes contained in news reports and announcements, not structured data

6 Qualitative markers require judgement

- Markers that are based on qualitative news reports, policy statements, or press releases require judgement to determine if reports truly reflect a change. A good rule of thumb is whether people and organization's actions are actually changing

7 Convert signposts and markers to action

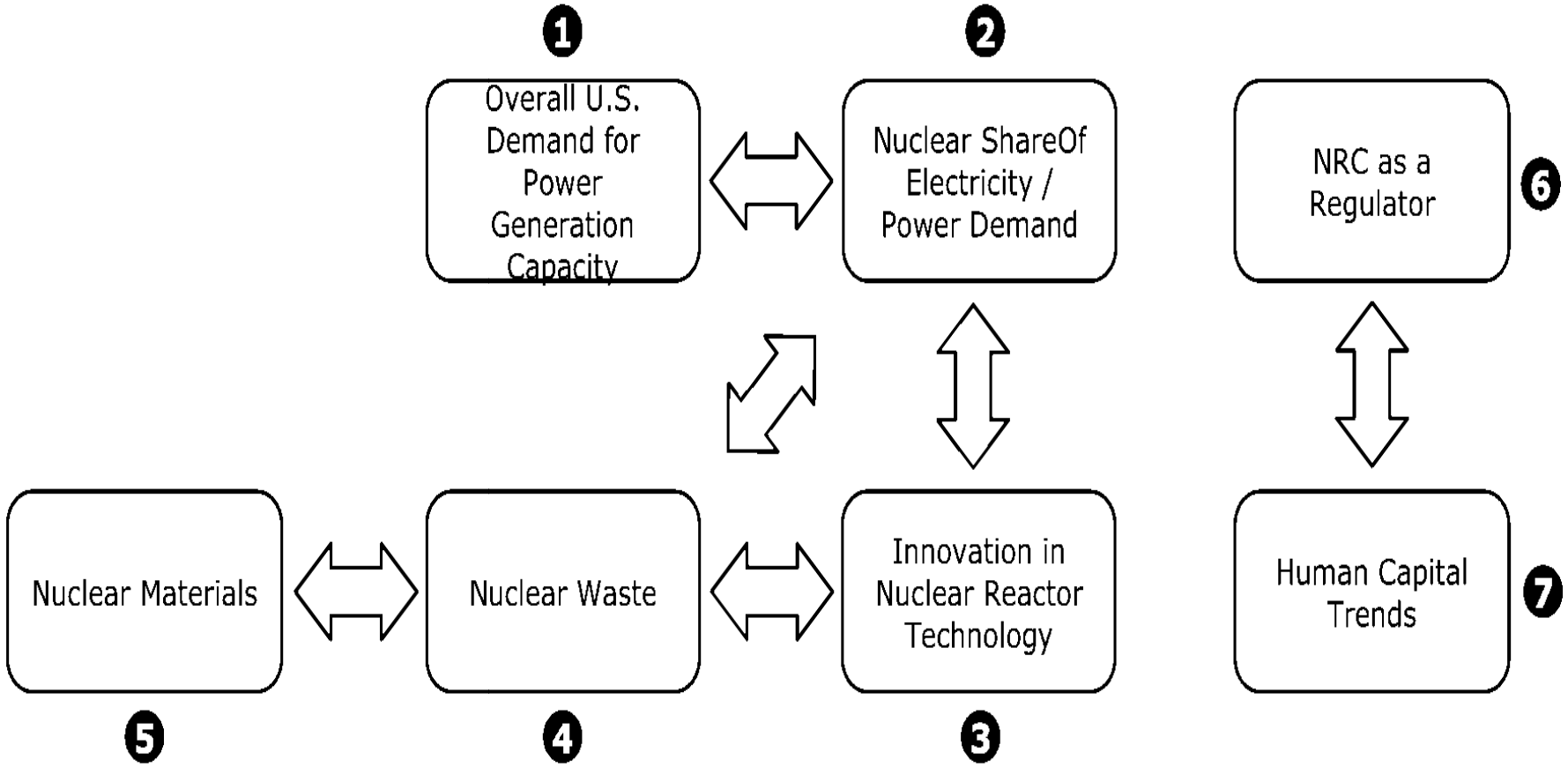
- There should be a process that takes the signposts and markers and uses them to anticipate how the future will unfold, and thus informs decision-making on what strategy and actions to pursue

8 The list of markers is dynamic

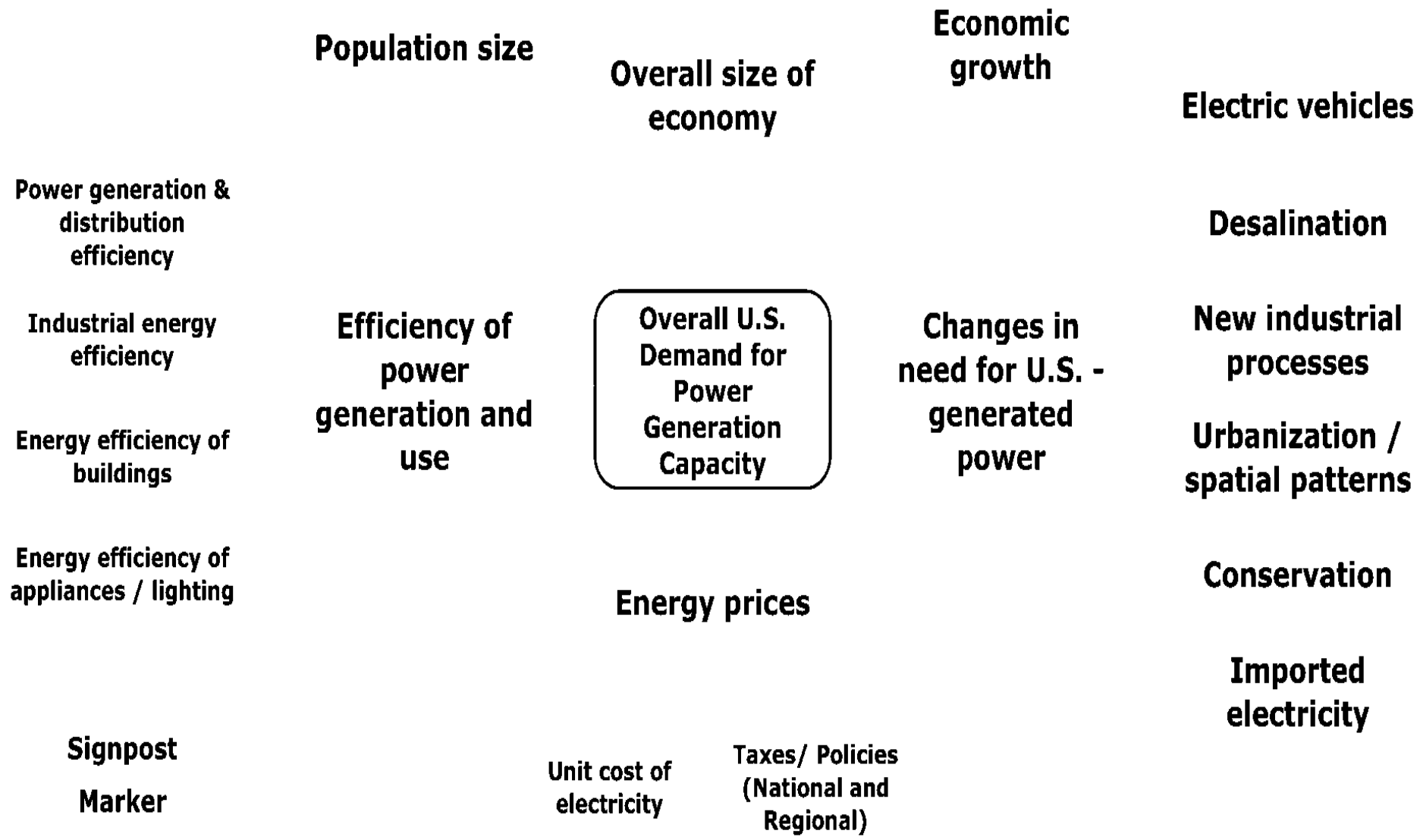
- The downselected list of markers is intended to be dynamic, not static. There may be a need to intensify the regularity of tracking of a marker that is becoming more significant, or to change the metrics used

Appendix: Systems Diagrams of Signposts and Markers

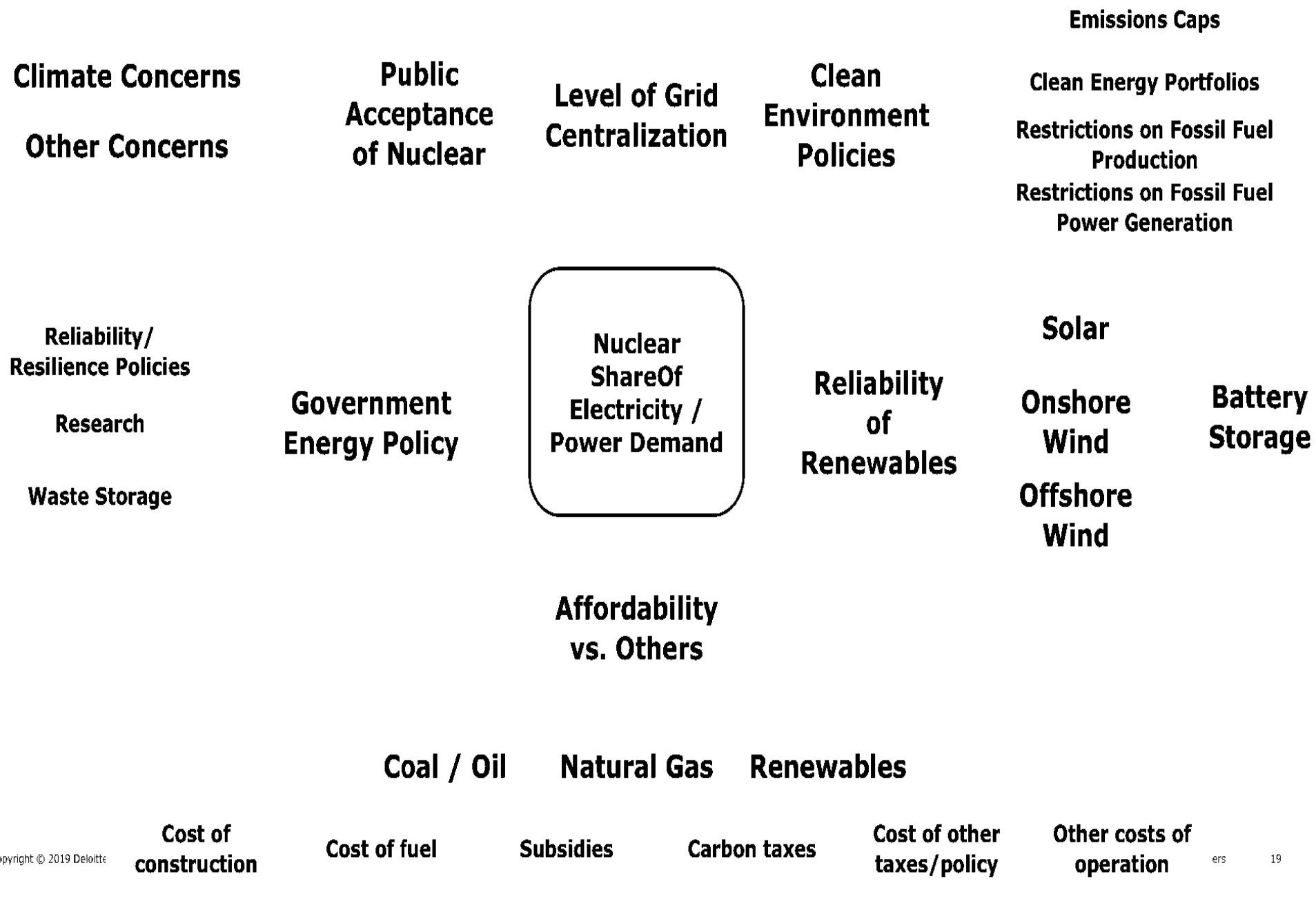
There are 7 systems diagrams of potential signposts and markers in this appendix



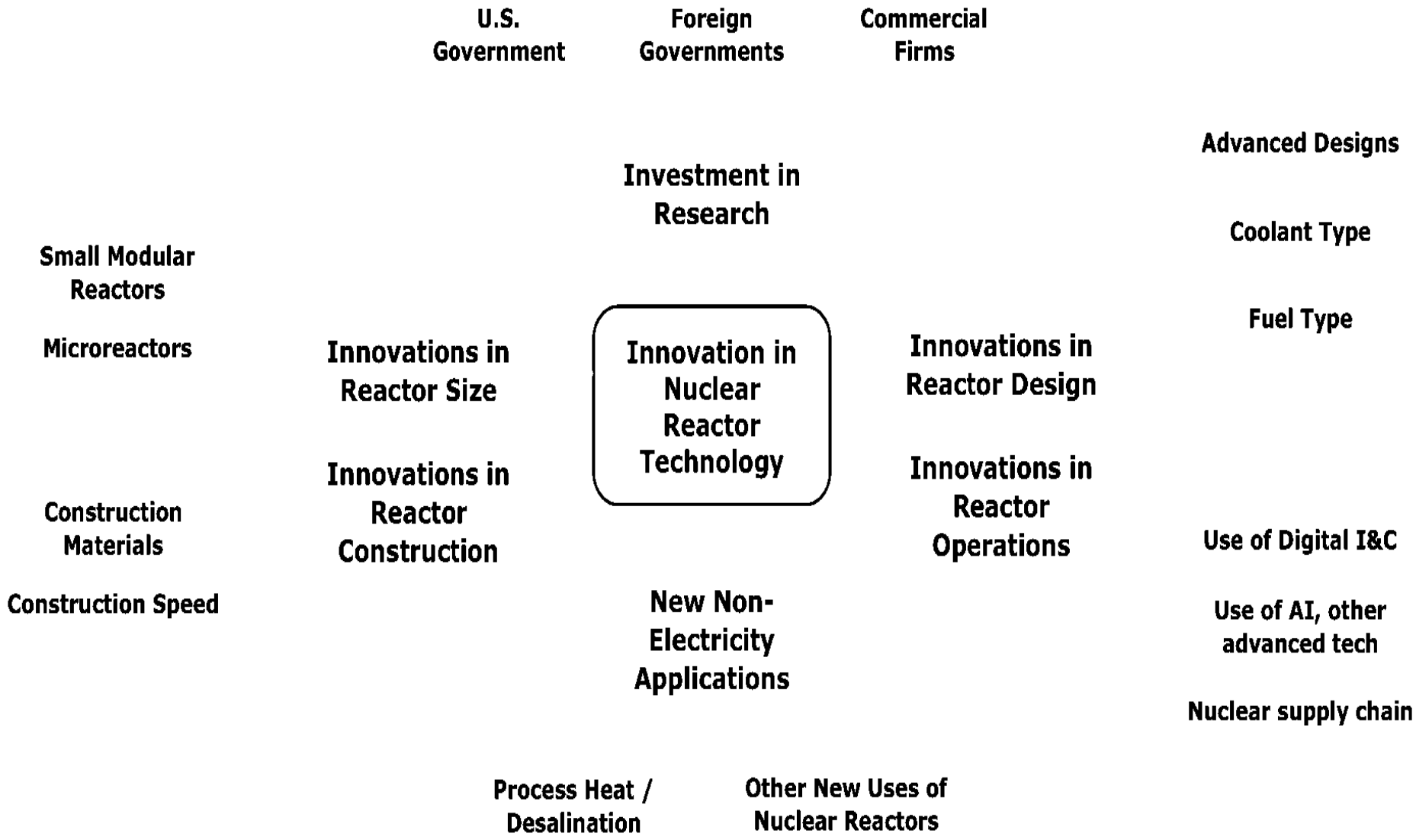
Systems Diagram 1: Overall U.S. Electricity/Power Demand



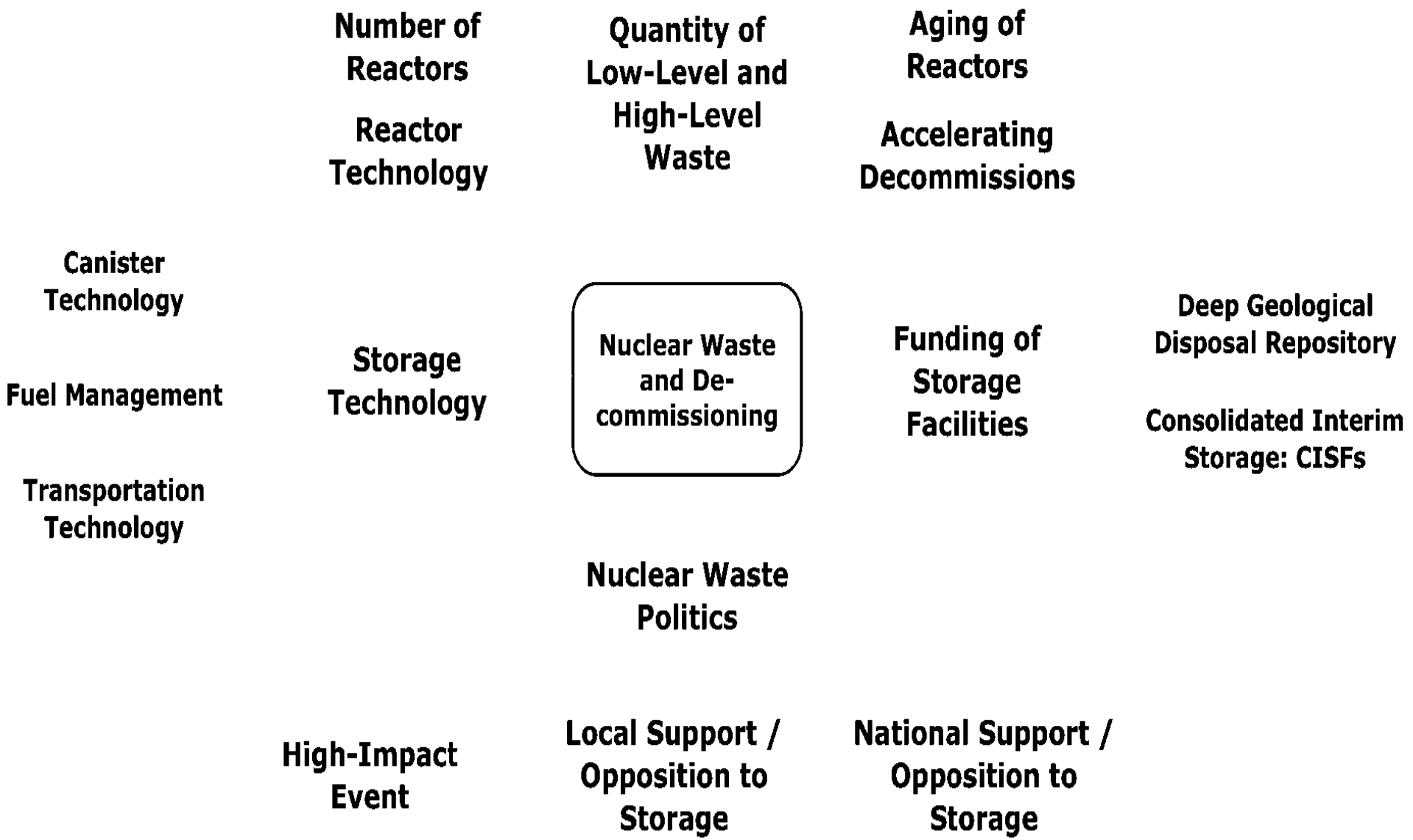
Systems Diagram 2: Nuclear's Share Of Electricity / Power Demand



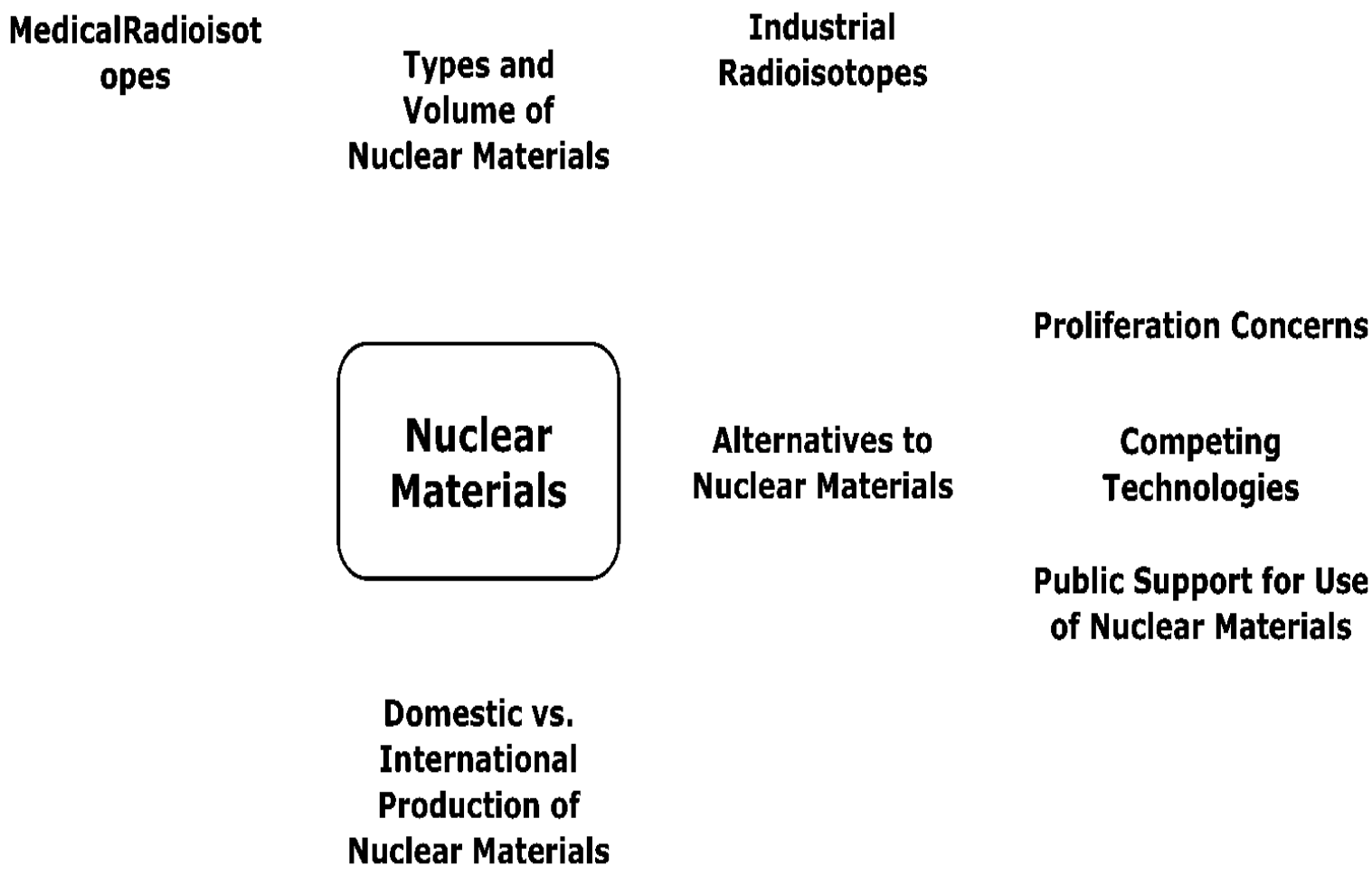
Systems Diagram 3: Level of Innovation in Nuclear Reactor Technology



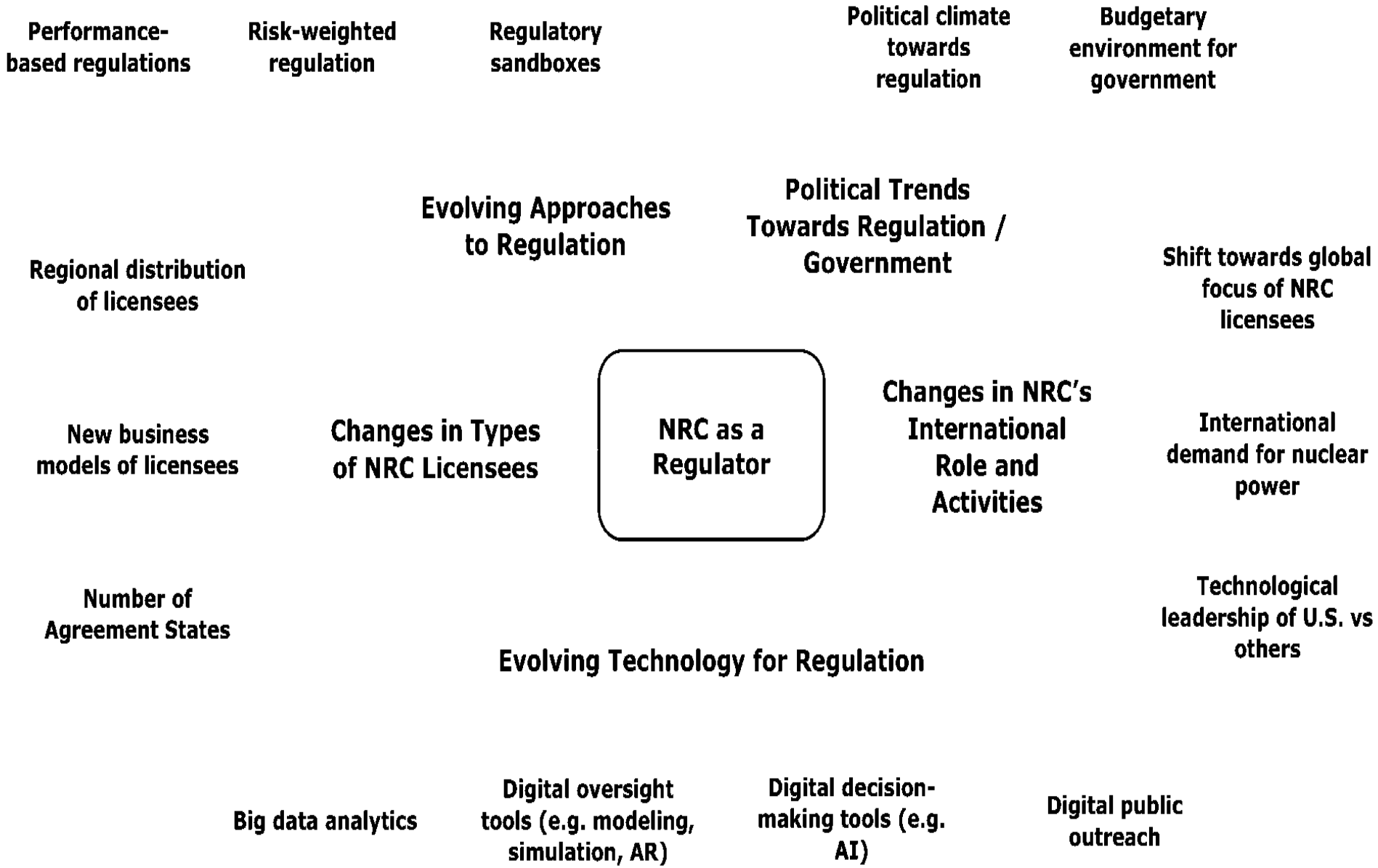
Systems Diagram 4: Nuclear Waste and Decommissioning



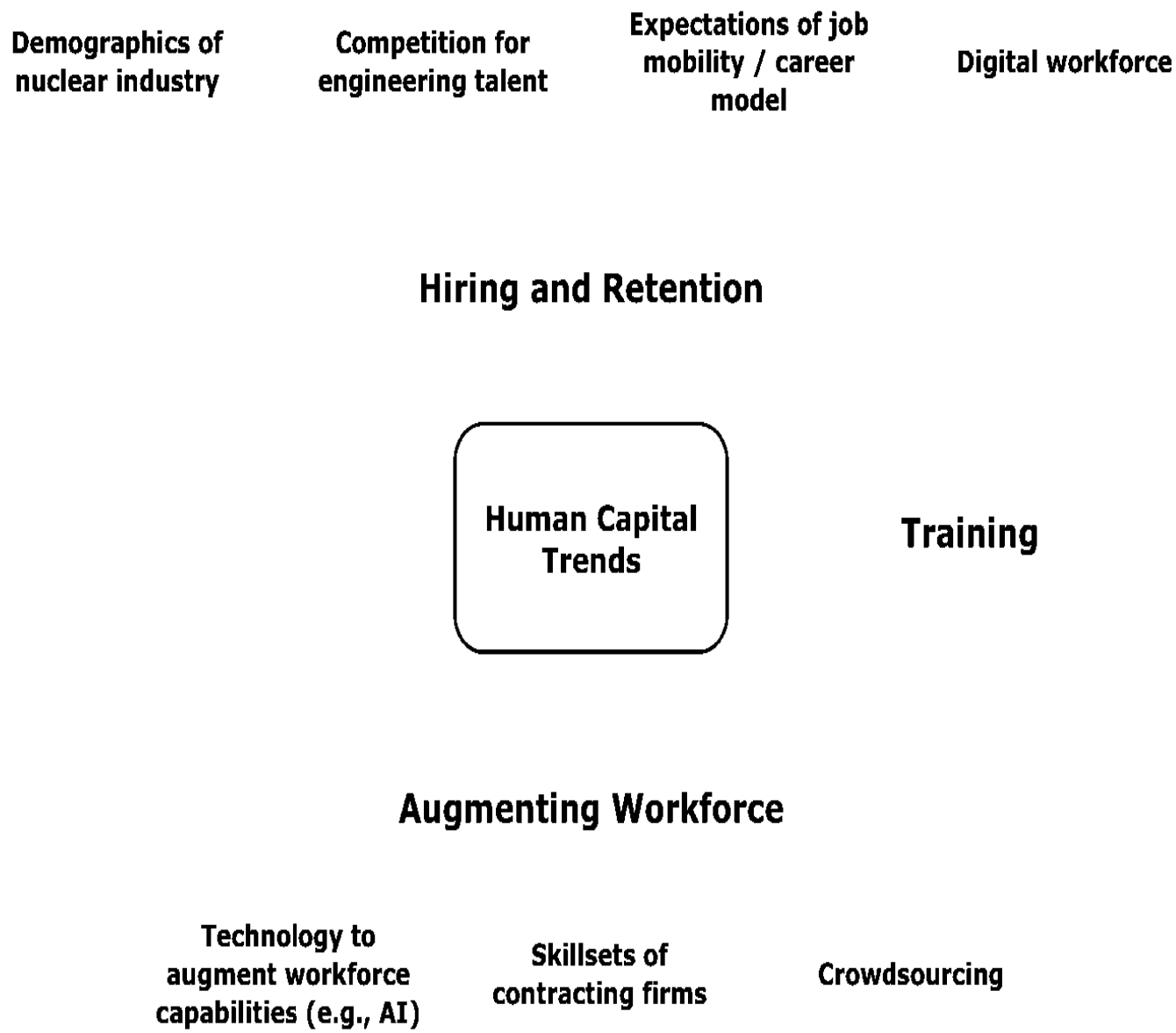
Systems Diagram 5: Nuclear Materials



Systems Diagram 6: NRC as a Regulator



Systems Diagram 7: Human Capital Trends



Crosswalk: Markers Against Scenarios

	Nuclear Nirvana	What's Old is New Again	Gone With the Wind	Great Idea, But NIMBY
Size of economy			▼	▼
Economic Growth			▼	▼
Overall demand for electricity generation			▼	▼
Growth of electric vehicle fleet			▼	▼
Stated commitments of major car manufacturers regarding electric vehicle production			▼	▼
Growth in desalination and other energy-intensive industrial processes			▼	▼
Efficiency of power generation	▼	▼	=	=
Energy intensity of economy	▼	▼	=	=
Energy efficiency of commercial buildings	▼	▼	=	=
Energy intensity of residential buildings	▼	▼	=	=
Breakthrough energy efficiency technology	▼	▼	=	=
Increase in demand-response programs, including use of smart metering and smart office/home technology to manage energy use	▼	▼	=	=
Imports of electricity from Canada	▼	▼	=	=
Public attitudes to nuclear energy			▼	▼
Public attitudes to climate change			▼	▼
Public attitudes to the environment			▼	▼

▼ The marker is increasing or more likely to have occurred in this scenario

▼ The marker is decreasing or less likely to have occurred in this scenario

= Marginal Change

Crosswalk: Markers Against Scenarios

	Nuclear Nirvana	What's Old is New Again	Gone With the Wind	Great Idea, But NIMBY
Major nuclear-related events/accidents in the U.S.	▼	▼		
Major nuclear-related events/accidents outside the U.S.	▼	▼		
Safety or security events	▼	▼		
Planned deployment of advanced non-light water reactors in the U.S., on the assumption that advanced reactors are likely to feature increased safety and security			▼	▼
Reliability of solar / onshore wind / offshore wind	▼	▼		
Feasibility of storage technology	▼	▼		
Overall cost of energy production by source			▼	▼
Capital financing costs			▼	▼
Operating expenses			▼	▼
Fuel costs			▼	▼
Federal and state subsidies and taxes, including carbon taxes, and how they affect different energy sources			▼	▼
Federal and state policy statements on energy subsidies and taxes			▼	▼
Public announcements by power generation companies on strategy			▼	▼
Financial health of nuclear power companies			▼	▼
Growth of small-scale energy production	▼	▼		
Federal and state policy statements on energy grid	▼	▼		

▼ The marker is increasing or more likely to have occurred in this scenario

▼ The marker is decreasing or less likely to have occurred in this scenario

= Marginal Change

Crosswalk: Markers Against Scenarios

	Nuclear Nirvana	What's Old is New Again	Gone With the Wind	Great Idea, But NIMBY
Creation of CO2 emission caps			▼	▼
Federal and state policy statements on emission limits			▼	▼
Inclusion or exclusion of nuclear power into state clean energy portfolio standards			▼	▼
Federal and state policy statements on clean/renewable energy portfolio standards			▼	▼
Restrictions on fossil fuel production/generation			▼	▼
Major safety events/accidents related to non-nuclear sources of power, especially fracking			▼	▼
Introduction of reliability and resilience policies (e.g. policies introducing minimum levels or percentages of energy supply that is nuclear in order to maintain reliability of baseload)			▼	▼
Federal and state energy policy statements reflecting a shift away from laissez-faire energy market policy			▼	▼
Changes in waste storage policy			▼	▼
Plans for advanced non-light water reactors in the U.S.		▼	▼	
Plans for advanced non-light water reactors globally		▼	▼	
Plans by commercial firms to deploy advaced non-light water reactors in the U.S.		▼	▼	
Developments by DoD and other government designers of nuclear reactors		▼	▼	
Developments by nation-states and state-owned enterprises		▼	▼	
Pre-application meetings with regards to small modular reactors (both U.S. and global)		▼	▼	
Pre-application meetings with regards to micro-reactors (both U.S. and global)		▼	▼	

▼ The marker is increasing or more likely to have occurred in this scenario

▼ The marker is decreasing or less likely to have occurred in this scenario

= Marginal Change

Crosswalk: Markers Against Scenarios

	Nuclear Nirvana	What's Old is New Again	Gone With the Wind	Great Idea, But NIMBY
Externally stated strategies of major firms (power generation companies, nuclear reactor design firms etc.)			▼	
Developments by DoD and other government designers of nuclear reactors		▼	▼	
Announcements by nation-states and state-owned enterprises		▼	▼	
Amendment reviews for first-of-a-kind technology		▼	▼	
Speed of construction			▼	
Changes in materials used and construction techniques			▼	
Innovations in uses of technology such as digital I&C, AI within reactors, accident-tolerant fuels		▼	▼	
Plans for reactors that use nuclear for process heat e.g. for desalination			▼	
Levels of nuclear R&D funding from the federal government		▼	▼	
Levels of nuclear R&D funding by foreign governments		▼	▼	
Spent fuel			▼	▼
Number of reactors	▼	▼		
Aging of reactors	▼	▼		
Number of reactors being decommissioned	▼	▼		
Funding for deep geological disposal repository			=	▼
Funding for CISFs			=	▼

▼ The marker is increasing or more likely to have occurred in this scenario

▼ The marker is decreasing or less likely to have occurred in this scenario

= Marginal Change

Crosswalk: Markers Against Scenarios

	Nuclear Nirvana	What's Old is New Again	Gone With the Wind	Great Idea, But NIMBY
Advancements in canister technology, fuel management, and transportation technology			=	▼
Research in storage technology including canister technology, fuel management, transportation technology			=	▼
External announcements by firms including 3rd party decommissioning firms that signal changes in efficiency of decommissioning			=	▼
State/local laws passed relating to nuclear waste			▼	▼
Federal laws passed relating to nuclear waste			▼	▼
Public attitudes to nuclear waste			▼	▼
High impact events	▼	▼		
Policy statements related to nuclear waste by Congress, federal agencies and state governments			▼	▼
Demand for new uranium recovery facilities, expansions, restarts, and renewals			▼	▼
Demand for new uranium recovery facilities, expansions, restarts, and renewals			▼	▼

▼ The marker is increasing or more likely to have occurred in this scenario

▼ The marker is decreasing or less likely to have occurred in this scenario

= Marginal Change

Crosswalk: Markers Against Scenarios

	Nuclear Nirvana	What's Old is New Again	Gone With the Wind	Great Idea, But NIMBY
Materials licensing actions				=
Commercial firm or researcher announcements of new diagnostic and therapeutic uses of medical radioisotopes				=
Commercial firm or researcher announcements of new industrial uses of radioisotopes				=
Policy statements by government security agencies (e.g. NNSA) on proliferation concerns		=	=	
Policy statements by government security agencies on developing alternatives to nuclear materials	▼	▼		
Development of nuclear materials production			▼	▼
Regional distribution of NRC licensees			=	=
Digital public outreach			=	=
New business models for potential NRC licensees		=	▼	▼
Adoption of new regulatory approaches by other peer federal agencies				
Adoption of new regulatory approaches by other nuclear regulators globally		=	▼	
Budgetary environment for government		=	▼	=
Administration policy statements on budgets		=	▼	=
Availability of big data analytics and digital tools for augmenting decision-making such as AI		=	=	
Availability of digital oversight tools such as modeling / simulation, augmented reality that could complement or physical inspection		=	=	

▼ The marker is increasing or more likely to have occurred in this scenario

▼ The marker is decreasing or less likely to have occurred in this scenario

= Marginal Change

Crosswalk: Markers Against Scenarios

	Nuclear Nirvana	What's Old is New Again	Gone With the Wind	Great Idea, But NIMBY
Shift towards global focus of NRC licensees	=		▼	
Current international demand for nuclear power			▼	
Projected growth in international demand for nuclear power		=	▼	
Technological leadership of U.S. in nuclear power vs others		=	▼	▼
Plans for development of advanced reactors outside the U.S.			▼	
Ability to attract young talent to the nuclear industry as a whole		▼	▼	▼
Ability to attract young talent to the NRC	=		▼	▼
Competition for engineering talent in the energy industry		=		
Pipeline of nuclear engineers	=	▼	▼	▼
Expectations of career model and time spent at NRC		=	▼	
Adoption of workforce augmentation technology (e.g. AI, RPA) by nuclear industry, other peer federal agencies, and/or international nuclear regulators		=	=	

▼ The marker is increasing or more likely to have occurred in this scenario

= The marker is decreasing or less likely to have occurred in this scenario

Marginal Change